Beef Muscle Characteristics as Related to Carcass Grade, Carcass Weight, and Degree of Aging

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It is quite generally believed that the physical, chemical, histological and organoleptic characteristics of beef are influenced by the genetic background of the animal and by the ante mortem and post mortem treatment received by the animal and the carcass. Some of these characteristics are interrelated and can be readily recognized and evaluated by visual observation of the carcass. However, other properties and interrelationships are much more obscure.

The investigations reported here were undertaken to provide fundamental information on the various properties of beef. It was hoped that this information would provide a sound, scientific basis for the development of more objective methods for grading carcass beef.

PREVIOUS INVESTIGATIONS

Many earlier investigations have indicated the influence of the chemical, physical, and histological properties of beef on its organoleptic characteristics. The relationship of some of the properties to carcass grade and weight has been shown also.

Sherman (*35*) [1] has expressed some doubt that carcass grade is a dependable index of juiciness or tenderness of beef. However, other investigators (*4*, *30*, *39*) have shown that carcass grade is a reliable criterion of organoleptic quality.

Since most current systems of evaluating meat quality are based on subjective observations, much research has been directed toward developing objective techniques for determining beef quality. Investigators have reported relationships between tenderness and mechanical shear values (*4*, *17*, *33*, *34*), intramuscular fat content or marbling (*3*, *22*, *39*), collagen content (*22*, *25*, *28*), muscle fiber size (*21*), extent of muscle autolysis (*32*), electrical conductance (*15*), and other physical, chemical, and histological properties. In the same way, juiciness has been stated to be related to fat content (*2*, *6*), expressible fluid from cooked meat (*37*), and fat content of the press fluid (*13*). The distinctive flavor of cooked meat has been attributed, at least by implication, to creatine and creatinine (*35*)), sulfur compounds

[1] Italic numbers in parentheses refer to "Literature Cited" pages 42, 43, 44, 45.

(*5*, *8*), and various nonprotein nitrogenous compounds (*8*, *35*). The European work on this subject was reviewed and summarized recently by Heim (*20*).

In most cases the relationships between physical, chemical, histological, and organoleptic properties were estblished on a limited number of samples. Also, the relationships were not close enough to justify using the objective measurements as criteria for organoleptic quality or carcass classification.

MATERIALS AND METHODS

Carcasses Used. To accomplish the objectives of the experimentation it was necessary to select some particular classification of carcass beef that could be more or less closely reproduced over the period of the investigation. The groups chosen are shown in table 1. Three carcasses from each group were selected each year for a 3-year period (1949–51),[2] making a total of 153 carcasses studied. Since it obviously would be impossible to study all parts of each carcass in a project of this scope, two commercial wholesale cuts were selected for study—the rib cut and the round. In general, samples were obtained as follows: Cattle expected to yield carcasses of the specifications shown in table 1 were selected in the yards at Chicago by representatives of the Agricultural Marketing Service, purchased and slaughtered by one of the major meatpacking companies in Chicago, and the carcasses graded by a representative of the Meat Grading Branch, Livestock Division, AMS. Three carcasses of each lot were selected as most closely approaching the average of the grade classification desired, and the rib cuts from the three carcasses and round from one of these carcasses were removed and transported to the laboratory. In some cases it was not possible to select live cattle that would meet the proper car-

TABLE 1.—*Carcasses studied—carcass grade and weight and date sampled*

Carcass grade	Approximate carcass weight	Date sampled
	Pounds	
Prime	500	January June August
Prime	800	January June August
Good	400	January June August October
Good	650	January June August October
Commercial cows	650	January August October

[2] Beef grades were revised in December 1950, but all results reported in this bulletin are on the basis of the grades currently in use.

cass classification, and samples were cut from carcasses of the appropriate grades from the cooler stocks of the packing company. Detailed descriptions of the carcasses selected and the feeding history of the animals (when known) were obtained for future reference in interpreting results.

Generally, the cuts for study were obtained approximately 48 hours after the animals were slaughtered. The *Longissimus dorsi* of the rib and the *Semitendinosus* muscle of the round were sampled immediately, and after 2 and 4 weeks' aging of the cuts at 33°–35° F. (During the third year of the study, cuts from the lightweight carcasses in each of the grades were aged for only 2 weeks.)

Sampling Procedure. Immediately upon arrival of the wholesale cuts at the laboratory they were photographed and sampling performed in a cooler at 45° F. as follows: From the left rib cut of each carcass, two rib steaks, 1½ inches thick, were cut for cooking. The 12th-rib steak was used for chemical and histological studies on the cooked meat while the 11th-rib steak was used for panel scoring of palatability of the cooked meat. The 11–12 rib section was removed from the right rib cut and the ribeye muscle (*Longissimus dorsi*) was carefully removed and freed from all adhering fat and connective tissue. The muscle was then cut into two approximately equal pieces parallel to the grain of the meat. Conductance measurements and penetrometer readings were made immediately on the freshly cut pieces. Thin slices were removed from the center of the muscle for histological examination and biochemical studies. Three or four cylinders, one-half inch in diameter and approximately 2½ inches long, were carefully cut out parallel to the muscle fibers and used for shear tests. The remainder of the muscle section was cut into pieces, ground through a food chopper with plates having ¼-inch holes, and thoroughly mixed by hand. Portions of the ground sample were used for all other physical and chemical determinations.

The rump was removed from the left round by cutting perpendicular to the *Semitendinosus* muscle about 1½ inches from its top end. Two slices, each 1½ inches thick, were then cut from the round for cooking. The slice containing the top of the *Semitendinosus* muscle was used for panel scoring for palatability and the adjacent slice used for chemical and histological studies on the cooked *Semitendinosus* muscle. The rump was removed from the right round and a slice containing approximately the top third of the *Semitendinosus* muscle was cut off, the *Semitendinosus* muscle removed and freed from all adhering fat and membranous tissue. It was then treated exactly like the section of the right ribeye described above.

For chemical, physical, and histological studies on cooked meat, the steaks were cooked the day the samples were taken and held overnight at 45° F. The following morning the *Longissimus dorsi* and *Semitendinosus* muscles were removed, the "browned" surfaces (about one-eighth inch thick) removed, and the remainder treated as described above for raw tissue.

Immediately after removal of the fresh sections from the rib cuts and rounds, the cuts were weighed and placed in a constant temperature room (34° ±1° F.) for aging. At the end of 2 weeks the cuts were removed to the 45° F. cooler, weighed to determine weight loss, and any moldy, slimy, or dehydrated surface on the aged cuts was carefully trimmed off. At this time two rib steaks involving the 9th and 10th ribs were cut from each left rib cut for cooking, the 10thrib steak was used for chemical and physical analyses and the 9th-rib steak was used for panel scoring for palatability. The 9–10 rib section was cut from the right rib cut and the ribeye muscle removed and treated exactly as in the case of the unaged sample. The remainder of the 9–10 rib section was separated into fat, lean, and bone and the weights of these components used to estimate the composition of the entire carcass. The middle sections of the rounds were removed in the same manner as the first cuts and the *Semitendinosus* muscle treated in exactly the same manner as the unaged sample. The remaining portions of the cuts were again weighed and returned to the 34° F. room. At the end of 4 weeks the final sampling was made exactly as described above except that the 7–8 rib section from each rib cut and the section of each round containing the lower portion of the *Semitendinosus* muscle were used for cooking and analyses.

Determination of Carcass Composition. The composition of carcasses from which the commercial cuts were obtained was estimated, as described by Hankins and Howe (*18*), from the amount of separable fat, lean, and bone of the 9–10 rib section. Preliminary investigations on 30 carcasses studied the first year showed that separable fat, lean, and bone of the 9–10 rib cut were almost identical with that of the 9–11 rib cut, so the same formulas proposed by Hankins and Howe were used for calculating carcass composition from the separable fat, lean, and bone of the 9–10 rib cut.

Physical Properties of the Meat. Marbling. The ratings for marbling were purely subjective on a rating scale of 1 to 5 with the following descriptive terms used: (1) Very abundant and extensive, (2) abundant and extensive, (3) moderate, limited distribution, (4) traces, (5) non visible.

Color Ratings. Subjective color ratings for the fat and lean were made by color comparison with standard Munsell color plates for meat (*29*). Comparisons were made under soft white fluorescent light on a cut surface exposed to the air for 1 hour at 45° F. With this system of color rating, the lower the numerical index the more desirable the color.

pH. The pH determinations were made with a glass electrode apparatus as follows: Place 10 grams of ground meat in a small beaker, add 20 ml. distilled water, stir well, and let stand for several minutes. Read the pH of the slurry using a glass electrode pH meter.

Shear Strength. Shear values were determined with the Warner-Bratzler shear apparatus (*7*) on one-half inch diameter cylinders of raw or cooked meat at 45° F. Care was taken to keep the cylinder sharp and to cut in such a way that the cylinder was parallel to the grain of the meat. Portions of the muscle having large fatty deposits or extensive facia streaks were avoided. A total of 10 shear values from 4 cylinders gave a satisfactory average shear value (standard error of ± 0.5 lb.).

Electrical Conductivity (Resistance). Electrical resistance measurements on meat (*15*, *32*) have been variable and subject to considerable error largely because of instrumental difficulties and the difficulty of representative sampling. It was found that these difficulties could be largely overcome by using a double-pronged electrode with a 300-ohm shunt between the two electrodes (to prevent drift due to electrode polarization) in conjunction with a standard portable electrolytic resistance indicator operating on 110-volt, 60-cycle alternating current (fig. 1). Readings were made on meat freshly cut

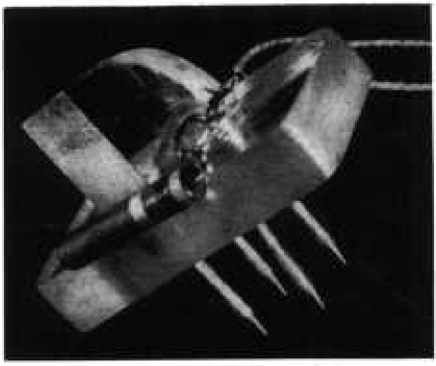

Figure 1.—The double pronged electrode with resistance shunt used to determine the electrical resistance of meat.

parallel to the grain of the meat. Resistance was read rapidly to avoid possible errors due to electrode polarization. Readings were made in triplicate parallel to the grain of the meat and in triplicate perpendicular to the grain on each sample. The specific conductance of the sample was calculated from a "cell constant" determined by calibrating the electrode with solutions of known conductivity.

Penetrometer Readings. These readings should be indicative of the force necessary to separate the muscle fibers. The method used was as follows: Place a piece of muscle tissue approximately 10 cm. × 5 cm. by 2.5 cm. thick (cut with the long dimension parallel to the grain of the meat) on the platform of a standard penetrometer carrying a 200-gram weight. Adjust the needle (described below) oriented with its longer cross section parallel to the grain of the meat so that it just touches the surface of the meat. Set the scale to zero and release the needle. Record the depth to which the needle penetrates in 15 seconds. Take a total of five readings on each sample, avoiding obvious deposits of fat or connective tissue as far as possible. The needle used had what may best be described as a "spade" point. If sections were taken perpendicular to its axis a family of ellipses of increasing size would be obtained. However, the ends at the long axis of these ellipses would be pointed. The needle used had a maximum width of 0.6 cm. and a maximum thickness of 0.4 cm. at 1.2 cm. from the point. All penetrometer readings were made on raw and cooked meat at 45° F.

Firmness. Objective firmness readings were made on raw and cooked meat at 45° F. in the same manner as penetrometer readings except that the penetrometer was equipped with a needle having a ½-inch hemispherical point which only depressed the meat but did not penetrate.

Press Fluid. This determination was made with a Carver laboratory press equipped with a cylinder 2¼ inches in diameter. Press fluid on raw meat was determined at a temperature of 45° F. as follows: Pack the cylinder with 50 grams of freshly ground meat in 5 layers (separated by filter papers) containing approximately 10 grams each. Place a filter paper, a gauze mat, and a thin rubber mat at the top and bottom of the meat column. Place the cylinder in the press and raise the pressure slowly to 2,500 pounds per square inch in 10 minutes and hold at this pressure for 5 more minutes. Deduct the weight of the press cake from the original weight of the meat to obtain press fluid. For cooked meat, the procedure described by Tannor, Clark, and Hankins (*37*) was used.

Water Imbibition. The following empirical procedure, based on the method described by Hall (*16*), was used. Cut 20 grams of ground meat with 75 ml. of water in a high-speed electric blender for 20 seconds. Transfer to centrifuge tubes using 25 ml. water to wash the last of the slurry into the tubes. Allow to stand overnight at 45° F. Centrifuge for 5 minutes in an angle centrifuge at 3,500 rpm. Decant the liquid and measure. Subtract the amount from the original 100 ml. water added to obtain "imbibed" water.

Chemical Analyses. MOISTURE, CRUDE FAT, CRUDE PROTEIN, CRUDE ASH. These analyses were made on all raw samples of meat using the official methods (*31*) of the Association of Official Agricultural Chemists. Total nitrogen determinations were also made on cooked samples.

NONPROTEIN NITROGEN. For this determination the following procedure was used. Cut 50 grams of the cold (45° F.) ground raw or cooked meat in an electric blender with 120 ml. cold phosphate buffer (pH 6.5) and 30 grams ice for 3 minutes. Centrifuge. Recut the residue for 3 minutes using ice and phosphate buffer. Centrifuge and repeat the extraction of the residue once more. Combine the filtrates in a 50-ml. volumetric flask and add slowly, with mixing, 100 ml. 20 percent trichloroacetic acid. Make to volume, mix, and let settle. Filter. Determine the total nitrogen in a 25-ml. aliquot of the protein filtrate with a macro Kjeldahl determination using $CuSO_4$ as the digestion catalyst (*31*).

AMINO NITROGEN. Amino nitrogen was determined in a suitable aliquot of the protein-free filtrate using the gasometric amino nitrogen apparatus described by Van Slyke (*38*). For the determination, the macro reaction chamber, the micro gas burette, a reaction time of 5 minutes and a shaking speed of 80 rpm were used.

CREATINE AND CREATININE. Suitable aliquots of the protein-free filtrate were used for the determination of these compounds. The method used was essentially that of Folin (*12*) except that creatine was dehydrated with hydrochloric acid solution according to the AOAC method (*31*) and the final optical density measurements of the colored solutions were made at 520 mμ in a photoelectric colorimeter. The concentration of creatinine in the colored solution was determined by reading the optical density values from a standard calibration curve prepared with pure creatinine.

SOLUBLE PROTEIN NITROGEN. The residue from the filtration following the trichloroacetic acid precipitation of the meat extracts was washed thoroughly with 4 percent trichloroacetic acid and subjected to a macro Kjeldahl nitrogen determination by the AOAC official method (*31*) using $CuSO_4$ as the digestion catalyst.

"VOLATILE" SULFUR. This determination was made on raw and cooked samples for the third year's study only. The method used was essentially that described by Diemair et al. (*10*). Five grams of the finely ground raw or cooked meat was cut in an electric blender with 50 ml. 0.039^N NaOH for 3 minutes and the mixture washed into the boiling flask with 50 ml. water. Ten to 15 ml. capryl alcohol and boiling chips were added and the distillation made as directed in the original method. The blue solution was transferred to a 500 ml. volumetric flask, made to volume and mixed thoroughly. After 10 minutes the optical density of the colored solution was measured in a photoelectric colorimeter at 670 mμ. The methylene blue in the unknown was determined by reading the optical density value of the unknown from a standard curve prepared with solutions of methylene blue, *p*-aminodimethylaniline and Reisener's solution. The "volatile" sulfur content of the sample could then be calculated since the sulfur content of methylene blue is known.

EXTRACTABLE COLOR. This determination was made on the third year's raw meat samples by the method described by Husaini et al. (*23*). Since no color standard was used, results are expressed only as the optical density values of the extract from 25 grams meat with 125 ml. water. For the optical density measurements, the clear filtrate was placed in 19 mm. cuvettes and measurements made at 540 mμ in a Coleman model 12 spectrophotometer.

COLLAGEN. Only a few chemical determinations for collagen were made since it was found that the results were closely related to those obtained by the histological method which will be described later. The chemical method used for the collagen determinations was essentially that described by Lowry et al. (*24*) with a 3-hour autoclave treatment at 15 pounds pressure to gelatinize the collagen. The final collagen nitrogen determination was made by Nesslerization after a Kjeldahl digestion of the solubilized collagen. The color formed by the Nessler's reagent was read in a Coleman model 12 spectrophotometer at 480 mμ against a water blank within 1 minute after the Nessler's solution was added. The amount of collagen nitrogen present in the solution was determined by reading the optical density values obtained from a standard curve prepared with known amounts of amonium sulfate.

Histological Determinations. For histological studies, two strips about 3 cm.×8 cm. were cut from each sample parallel to the muscle fibers with a "valentine" knife consisting of two stainless steel blades mounted parallel to each other. A similar strip was cut from each sample perpendicular to the muscle fibers for transverse sections. All strips were immediately fixed in fresh Zenker-formol (9 parts Zenker and 1 part neutral formaldehyde) for 8–10 hours, washed in cold running water overnight and subsequently processed and imbedded in celloidin by standard histological procedures. For longitudinal sections, a piece (approximately 10 mm.×15 mm.) of one of the longitudinal strips was imbedded in a celloidin block and a similar piece from the transverse strip was mounted in a celloidin block. The remainder of the fixed tissues was stored in alcohol for use if needed. Sections from the imbedded tissues were made on a Spencer Precision sliding microtome at 10 microns thickness with 3 consecutive sections mounted on each slide. Three slides of longitudinal sections and one slide of transverse sections were made for each sample. The longitudinal sections were stained as follows: One slide with Hematoxylin, Weigert's, and Van Giessen's for structural examination; one slide with Van Giessen's for collagen and fat determination; and one slide with Weigert's for elastin determination. The transverse section slide was stained for structural examination in the same manner as the first of the longitudinal sections.

SIZE OF PRIMARY AND SECONDARY MUSCLE BUNDLES AND INDIVIDUAL MUSCLE FIBERS. Transverse sections were used in these determinations. A slide was projected on the ground glass of the "Gamma Microflex" at 20 × magnification and the boundaries of several secondary muscle bundles were traced on a piece of lens paper spread over the ground glass. The number of primary muscle bundles in a representative secondary muscle bundle was determined at a magnification of 64 ×. The area of a representative primary muscle bundle was traced and the number of muscle fibers enclosed in it was recorded. A planimeter (Lasico, model 121) was used to determine the area of the various tracings. From these data the mean cross-sectional area of secondary muscle bundles, the mean cross-sectional area of primary muscle bundles, and the mean cross-sectional area of single muscle fibers could be calculated. The diameter of individual muscle fibers also was determined by using an eyepiece micrometer and counting the number of muscle fibers in a given distance in longitudinal sections. This latter method gave low values because not all fibers were cut at their diameter. The calculated diameter from cross-sectional area measurements gave high results because the area occupied by the endomysium within a primary muscle bundle is not subtracted. For this reason the mean value from the two methods of calculation was reported as the final value.

AMOUNT AND DISTRIBUTION OF COLLAGEN. Slides of longitudinal sections stained with Van Giessen's were used for evaluating the amount and distribution of collagen. The method for the histochemical quantitative estimation of collagen which was developed during this investigation has been described elsewhere by Wang (*40*).

AMOUNT AND DISTRIBUTION OF FAT. The histological estimation of both perimysial fat (occurring between muscle bundles) and endomysial fat (occurring between muscle fibers within muscle bundles) was made on the same slides used for collagen determination. The slide was projected to a screen at 25 × magnification and all fat areas outlined on onionskin copy sheets held over the screen. The proportion of fat in the section could then be determined by cutting out the tracings of fat areas, weighing them, and relating the weight to the weight of paper from the tracing of the entire section or by comparing the area of the fat locations as determined with a planimeter to the total area of the section.

Since the effect of fat on meat characteristics might be dependent on the amount of fat surface in contact with the surrounding tissue, a rough index of this surface was determined. The slides were projected on a screen and each group of fat cells was measured at its longest dimension. The sum of these measurements in a given area was designated "linear" fat.

ELASTIN AND SIZE OF ELASTIC FIBERS. Quantitative histochemical estimation of elastin was made on slides of longitudinal sections stained with Weigert's which stains elastic fibers dark blue against a light gray muscle fiber background. The same general technique was used as for the collagen determination except that the Densichron instrument was used without a filter.

For estimation of the diameter of the thickest elastic fibers, the slides with longitudinal sections stained with the complete stain were projected on the ground glass of the "Gamma Microflex" at a magnification of 2600 × and the elastic fiber diameter was measured with the aid of drafting dividers. The mean of at least 10 such measurements was calculated and used as the final reported value.

MUSCLE FIBER AUTOLYSIS. Since there is no objective histological method for determining the extent of muscle fiber autolysis, a subjective evaluation of the frequency and extent of muscle fiber breaks was made on slides with longitudinal sections. Although a numerical autolysis index was given to each sample, this has the usual limitations of any subjective evaluation.

Oxidative Enzyme Activity. The methods used for evaluating the activity of various oxidative enzymes in the samples studied in this investigation have been described in other publications (*1*, *26*, *27*).

Cooking Procedure. Preliminary tests indicated that differences in flavor, aroma, and tenderness of meat from carcasses of different grades were more pronounced in broiled steaks than in roasts. Consequently, all cooked samples were prepared by broiling steaks 1½ inches thick by the following procedure: Electric broilers equipped with variable transformers were adjusted and preheated to equilibrium so that the broiler temperature at the meat surface (about 4 inches below the element) would be 375° F. With the aid of skewer, a meat thermometer or thermocouple was inserted from the edge into the center of the ribeye muscle (for rib steaks) or the *Semitendinosus* muscle (for steaks from the round) equidistant from the two surfaces. The steaks were then placed in the broiler, allowed to cook for 15 minutes, turned over and allowed to cook until the internal temperature reached 150° F. They were then removed from the broiler and held until the internal temperature reached its maximum—usually 155°–158° F. Cooking losses were determined by weighing the raw and the cooked steaks and the drippings. Evaporation loss was calculated by difference.

Panel Scoring. Immediately after the steaks reached maximum temperature, the ribeye muscle (rib steaks) or the *Semitendinosus* muscle (round steaks) was removed, cut into eight pieces (always in the same manner) and the pieces were served warm to a panel of six judges who were previously screened and trained for discrimination and reliability. Each tester received a piece cut from the same muscle position from each of the three steaks scored at one time, and in addition a fourth piece which was a duplicate of one of the three samples. All samples were coded for blind judging. No panel member was sufficiently familiar with the project to know the the nature of the meat (grade or extent of aging) tested on any particular day.

The scorecard used for recording panel evaluation included ratings for aroma, flavor of fat, flavor of lean, tenderness, and juiciness. In addition, tasters were asked to indicate the nature of the meat characteristics by descriptive terms, if possible (fig. 2, p. 10).

Statistical Analysis of Data. Because of the tremendous volume of data obtained in this study some indications of variability, dependability, significance, and possible interrelationships were essential. Where five or more replicate determinations were made on the same sample (e.g., panel scores, shear tests, etc.) the standard error of the mean was calculated to indicate sample or analytical variability and assist in establishing limits of confidence. As the study progressed, careful inspection of the data and limited correlation and variance analyses indicated the characteristics of the meat which showed some evidence of interrelationships and some dependence on carcass grade and/or weight. On these bases, selected data were subjected to more complete analysis of variance and correlation studies by the Statistical Laboratory, Virginia Polytechnic Institute, Blacksburg, Va. Since not all classes of carcasses were sampled at all sampling periods (table 1), variance analysis for all classes for all 3 years could be made only in the January and August samples; inclusion of other groups of samples would have introduced bias into the analysis—that is, the data would not be "orthogonic." However, the complete data from each carcass grade could be subjected to variance analysis to determine the effect of weight, season, and year *within* the grade. In some cases this was done, and statements covering results from this treatment of the data are made although the actual statistical tables are not given. Some of the data were not complete enough to be suitable for variance analysis, and in some cases variations in results were so great that variance analyses would be of no value. Such data were not subjected to analysis of variance but

Sample No. ____________

SCORE CARD FOR MEAT

Date ____________________

Factor	10	9	8	7	6	5	4	3	2	1	
	Perfect	Excellent	Very good	Good	Low good	Fair	Low fair	Poor	Very poor	Extremely poor	Remarks
Aroma											
Flavor Fat											
Lean											
Tenderness	Extremely tender	Very tender	Tender	Moderately tender	Slightly tender	Slightly tough	Moderately tough	Tough	Very tough	Extremely tough	
Juiciness	Extremely juicy	Very juicy	Juicy	Moderately juicy	Slightly juicy	Slightly dry	Moderately dry	Dry	Very dry	Extremely dry	

Descriptive terms

Aroma

1. Mild ----
2. Sharp ----
3. Strong ----
4. Faint ----
5. Foreign ----
6. ____________________ ----
7. ____________________ ----
8. ____________________ ----

Flavor

1. Flat ----
2. Mild ----
3. Mellowed ----
4. Rich ----
5. Strong ----
6. Old ----
7. Bitter ----
8. Acid ----
9. Salty ----
10. Sweet ----

Color of lean

1. Light brown ----
2. Dark brown ----
3. Red and brown ----
4. Gray ----
5. Irridescent ----

Texture

1. Stringy ----
2. Dense, compact ----
3. ____________________ ----
4. ____________________ ----
5. ____________________ ----

Preference ____ Scorer ________________________________

(among samples judged at one time)

Figure 2.—The scorecard used for panel evaluation of broiled steaks.

mean values or ranges in values have been presented with appropriate evaluating statements. If any sample group contained less than three replicates, no mean value has been reported, but mean values for combined groups are presented in some instances.

EXPERIMENTAL RESULTS AND DISCUSSION

Influence of Grade, Weight, and Aging on the Characteristics of Beef

Carcass Composition

Based on the amount of separable lean, separable fat and separable bone in the 9–10 rib section, the calculated carcass composition values (table 2) indicate that Prime grade carcasses contained more fat and less lean and bone than Good grade carcasses, with Commercial cow carcasses intermediate between the two grades of younger animals. Analysis of variance on the combined data for the 3 years of the study (table 5a, appendix) shows that the light and heavy Good carcasses contained significantly less fat than did carcasses of Prime grade or Commercial cows. The combined data also show that carcasses sampled in January were fatter than those sampled in August.

The proportion of ribeye muscle in the rib cut (table 6, appendix) also reflects the greater degree of fatness of the Prime grade carcasses as compared to those of Good grade. In this characteristic also the Commercial cow carcasses were intermediate between the heavy Prime and the light Good grade carcasses.

Physical Properties

Lean Color. Analysis of variance on the combined 3 years' orthogonic data (August and January samples) shows that lean color of the raw ribeye muscle was significantly related to carcass grade and weight (table 7, appendix). Aging for 2 weeks definitely improved (lightened) the color of the lean of the ribeye. The overall average ratings for lean color of the *Longissimus dorsi* (table 8, appendix) suggest that this muscle from Prime grade carcasses has a lighter color than Good grade or Commercial cow carcasses. Analysis of variance on each individual year's results showed this to be true for the last 2 years of the study. Also, the lean color of all groups of samples was lightened significantly by aging except the ribeye from Commercial cow carcasses obtained the first and third years of the study. The effect of aging for the first 2 weeks was more pronounced than for the last 2 weeks.

TABLE 2.—*Carcass composition range of the different grades and weights (based on separable lean, fat and bone of 9–10 rib section)*

Carcass grade and weight	Separable lean	Separable fat	Separable bone
	Percent	*Percent*	*Percent*
Light Prime	46–59	31–43	11–16
Heavy Prime	45–57	31–43	10–14
Light Good	54–64	21–30	13–20
Heavy Good	47–64	20–42	11–20
Commercial cow	46–58	26–44	11–18

These data indicate that color of the lean of the ribeye, as determined by comparison with Munsell Color Plates, gives some indication of meat quality since the *Longissimus dorsi* from the higher grade of carcass and aged meat showed somewhat lighter color. Color ratings were not made on the *Semitendinosus* muscle.

Fat Color. With few exceptions the fat cover over the rib in all 153 carcasses studied was quite white. Only 15 carcasses, all in the Good and Commercial cow grade groups, exhibited Munsell Fat Color Numbers above 3, and only five carcasses had fat ratings above 4. Most of the fat color ratings were either 2 or 3, regardless of carcass grade, carcass weight or extent of aging.

Marbling. The extent of "marbling," or deposition of intramuscular fat in small areas, can best be illustrated by photographs of the cut surface of the rib (fig. 3). These photographs that show typical examples of the cuts from the different grades and weights indicate that marbling was somewhat greater in the Prime grade carcasses than in the Good grade or Commercial cow carcasses. Also, there is some suggestion that the heavy carcasses in each grade were more highly marbled than the light carcasses. Subjective marbling ratings made on the ribeye during the last 2 years of study (102 carcasses) appear to support these general statements (table 9, appendix). Analysis of variance on each separate year's results supported this—i.e., Prime grade ribeye was significantly more highly marbled than Good grade ribeye, and the ribeye of heavy carcasses was more highly marbled than that of light carcasses of the same grade. The ribeye of Commercial cow carcasses had a degree of marbling significantly higher than the heavy Good grade carcasses but lower than heavy Prime grade carcasses. Analysis of variance on the 2 years' combined orthogonic data for the August and January samples (table 10, appendix) shows that the mean marbling ratings for the different grade and weight classes were very significantly different. The marbling rating of the ribeye was somewhat better the third year than it was the second, especially in the Good grade and Commercial cow carcasses. This could be the result of either a slight difference in grading between the 2 years or a consistent difference in the subjective marbling rating for the 2 years.

pH: The pH of fresh raw meat in the carcasses studied was not related to carcass grade or weight. Values for fresh raw *Longissimus dorsi* and *Semitendinosus* were usually in the range of pH 5.4 to pH 5.8, although values as low as 4.7 (in a heavy Prime carcass) and as high as 7.3 (in a heavy Good grade carcass) were observed. The meat with the extremely high pH was quite dark, as would be expected. Cooking the meat usually caused a slight but definite increase in pH. Aging at 34° F. usually resulted in a slight increase in pH (*ca* 0.2) of the raw meat, especially during the first 2 weeks. In several cases the pH decreased during the last 2 weeks of aging.

Shear Strength. The individual shear values on each sample of raw or cooked beef were quite reproducible; the standard error of the mean for the 10 individual determinations rarely exceeded 0.5 pound. When raw shear values for each year were subjected to analysis of variance it was found that the average shear value for Prime carcasses was less than that for Good or Commercial cow carcasses the first and second year but not the third year. There was some tendency for aging to decrease the shear value of raw ribeye, but grade and month interactions with aging (which were not consistent from

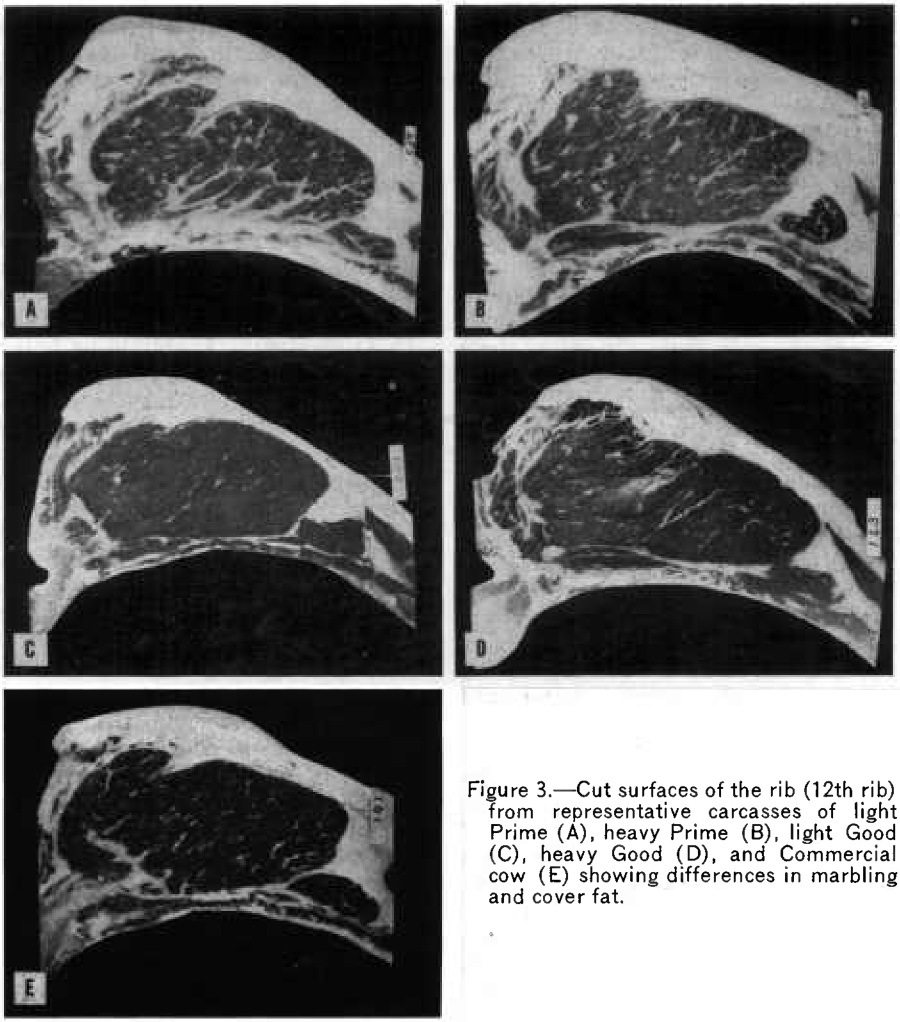

Figure 3.—Cut surfaces of the rib (12th rib) from representative carcasses of light Prime (A), heavy Prime (B), light Good (C), heavy Good (D), and Commercial cow (E) showing differences in marbling and cover fat.

year to year) completely overshadowed any simple aging effect. Also, the intramuscular variation in shear values for raw ribeye (p. 34) would account, at least in part, for the differences apparently due to aging. The average shear value in raw ribeye on the combined data for the 3 years varied from 4.2 to 9.4 (table 11, appendix). Analysis of variance on the orthogonic data for the 3 years showed only that samples obtained the third year had a significantly lower mean shear value (6.08) than did those obtained the first or second year (7.00 and 7.75, respectively).

Shear values of raw *Semitendinosus* from individual carcasses varied from 9.2 to 24.2 pounds but the differences were not associated with carcass grade, carcass weight, or extent of aging (table 12, appendix). The indicated increase in raw shear value of this muscle from 2 to 4 weeks' aging probably was not due to an actual change during aging but rather due to differences in muscle characteristics at the different positions from which the samples were taken. This will be discussed in more detail later (p. 35).

Cooking markedly increased the shear strength of *Longissimus dorsi* but decreased the shear strength of *Semitendinosus.*

For all carcass grades and weights, aging the raw wholesale cuts for 2 weeks caused very substantial reductions in the shear strength of the cooked meat (tables 11 and 12, appendix). Much less change occurred during the 2–4 weeks' aging period. Analysis of variance on the last 2 years' data, separately, also indicated that samples of ribeye obtained in January exhibited lower shear values on cooked meat than did samples obtained in June. Analysis of variance on the combined 3 years of orthogonic data showed significant differences for grade, aging, and years (table 13, appendix).

Specific Conductance. Although electrical resistance measurements were made both parallel and perpendicular to the "grain" of the meat, only those values for perpendicular measurements will be reported and considered here because the values from the two fiber orientations varied only slightly (the specific conductance parallel to muscle fiber was slightly higher in nearly all samples).

Values for the raw *Longissimus dorsi* varied from 83×10^{-5} to 400×10^{-5} mhos. Differences in specific conductance of the raw ribeye were not uniformly related to carcass grade, carcass weight, month sampled, or extent of aging (table 14, appendix). Aging for 2 weeks usually resulted in an increase in specific conductance. Additional aging sometimes caused a drop in specific conductance, especially in ribeye from Prime grade carcasses. Analysis of variance on each year's data indicated many interactions between grade, month sampled, weight, and extent of aging, but these were not uniform from one year to the next. Analysis of variance on the combined orthogonic data for the 3 years shows that aging for 2 weeks significantly increased the specific conductance and that this increase was more pronounced for the Good grade lightweight carcasses than for the other carcass groups (table 15, appendix). It should be pointed out here, however, that this apparent aging effect may be due entirely to intramuscular variation (p. 34). Samples obtained the second year had a significantly higher specific conductance than those obtained in either of the other 2 years.

Except for a few unaged samples, cooking the ribeye reduced the specific conductance. Aging the raw rib cut resulted in a reduction of the specific conductance of the cooked ribeye (table 14, appendix). This aging effect on the specific conductance of cooked ribeye was shown to be significant when each year's results was separately subjected to analysis of variance and also when the 3 years' combined orthogonic data were analyzed (table 16, appendix). As was the case for specific conductance on raw ribeye, however, this apparent aging effect may well be an artifact due to intramuscular variation (p. 34). Also, the samples obtained in August had a significantly higher conductance than those obtained in January. Samples obtained the third year had considerably lower specific conductance (cooked) than did ribeye samples studied the first 2 years. For each of the 3 years, specific conductance of the cooked ribeye was higher for Good grade carcasses than for Prime grade.

The specific conductance for raw *Semitendinosus* was usually slightly higher than that of the ribeye from the same carcass. Aging increased the conductance of the raw

Semitendinosus, particularly during the first 2 weeks (table 17, appendix). As was the case for ribeye, the specific conductance of cooked *Semitendinosus* was less than for raw, except for a few unaged samples. Specific conductance of neither raw nor cooked *Semitendinosus* was related significantly to carcass grade or weight.

The specific conductance of muscle tissue could be influenced by the amount and distribution of fat, the nature and distribution of inorganic ions, and the particular configuration and hydration of the proteins. The influence of aging on electrical conductivity reported here might well be related to changes in inorganic salts and protein hydration recently suggested by Wierbicki et al. (*44*). Cooking has been shown to cause a change in fat distribution (*41*) that could readily explain the increased electrical resistance of cooked meat as compared to raw. Protein denaturation and loss of inorganic salts and moisture during cooking would also logically cause a decrease in conductivity.

Penetrometer Measurements. This determination, which should indicate ease of muscle fiber separation, was made only on samples from the last 2 years of the study (102 carcasses). The results were not consistent for the 2 years, and the combined averages do not indicate any appreciable relationships between carcass grade or weight and penetrometer readings on raw ribeye (table 18, appendix). Two weeks' aging usually caused an increase in penetrometer readings on raw ribeye, followed by a decrease during the 2- to 4-week aging period. This trend was significant for Good grade and Commercial cow carcasses for both years of the study but was true for Prime grade ribeye only the second year.

Cooking decreased the penetrometer readings of the ribeye, usually by almost 50 percent. Aging the raw rib for 2 weeks usually resulted in an increase in penetrometer readings of cooked Prime ribeye but a decrease in penetrometer readings of cooked ribeye from Good grade and Commercial cow carcasses (table 18, appendix). Results for the 2- to 4-week aging period were too variable for definite conclusions to be drawn.

Penetrometer readings on raw *Semitendinosus* were appreciably lower than on raw ribeye. Aging resulted in an increase of penetrometer readings for both raw and cooked *Semitendinosus*, regardless of carcass grade or weight (table 19, appendix). No carcass grade or weight differences were observed.

These results are somewhat difficult to interpret. Since no significant relationship between grade and penetrometer readings on ribeye could be established, it might be postulated that muscle tissue does not vary in the tightness of binding of muscle fibers. This, however, is obviously not true since penetrometer readings for *Semitendinosus* were much lower than for ribeye.

The observed effects of cooking and aging on penetrometer values would suggest that protein hydration and/or the distribution of fat are important in determining the ease with which muscle fibers or muscle bundles can be separated.

Firmness Readings. This determination was made only on samples studied during the third year. The data (table 3) do not indicate that the firmness of raw *Longissimus dorsi* or *Semitendinosus* was related to carcass grade, carcass weight, or aging. Cooked meat was appreciably firmer than raw meat.

Press Fluid. This determination was made on samples obtained during the first 2 years of this study and yielded some very interesting results. The data show that ribeye from Prime grade carcasses yielded more fluid than that from Good

TABLE 3.—*Range of firmness values for* Longissimus dorsi *and* Semitendinosus *muscles from carcasses of different grades and weights*

[High values indicate low firmness]

Aging time (weeks)	0		2		4	
Muscle	*L.d.*	*Semi.*	*L.d.*	*Semi.*	*L.d.*	*Semi.*
Raw:						
Light Prime	69–125	61–99	66–128	48–99	--------	--------
Heavy Prime	61–103	57–96	48–96	45–103	49–116	72–105
Light Good	56–112	62–136	70–110	65–116	--------	--------
Heavy Good	54–94	48–93	63–108	70–83	53–103	42–101
Commercial cow	62–99	64–103	56–96	52–69	63–98	69–94
Cooked:						
Light Prime	17–62	21–54	28–60	46–57	--------	--------
Heavy Prime	14–59	15–44	22–46	15–38	24–50	40–43
Light Good	20–104	11–29	34–72	29–43	--------	--------
Heavy Good	20–68	16–30	24–52	26–31	18–65	31–58
Commercial cow	24–82	28–32	22–60	41–53	20–42	42

grade or Commercial cow carcasses, and that ribeye from carcasses sampled in June usually yielded less press fluid than samples obtained the other months (table 20, appendix). For all grades and weights, aging reduced the yield of press fluid from raw ribeye. Ribeye from heavy carcasses yielded more press fluid than ribeye from light carcasses of the same grade. Analysis of variance of the data showed all these differences to be statistically significant.

Cooked ribeye yielded more press fluid than raw but there were no consistent carcass grade or aging effects (table 20, appendix).

Press fluid data from raw *Semitendinosus* muscle showed the same carcass grade, weight, and aging relationships as the ribeye (table 21, appendix). Press fluid yields from cooked *Semitendinosus* were similar for all carcass grades and weights and different aging periods.

Press-fluid yield is an index of the "free" water in the meat. In other words, it indicates the water-binding capacity of the meat. Thus, the carcass grade, weight, and aging influence on press fluid reported here must reflect differences in the water-binding capacity of the tissue. Since fat has little or no ability to hold water, any differences in press-fluid yield must be attributed primarily to differences in the nature or condition of the muscle protein. The practical implications of these statements, particularly as related to meat quality, are not clearly defined.

Water Imbibition. This determination was made only on raw samples studied during the first year. Most of the values for raw meat were near 12 ml./20 g. (range of 8–20 ml./20 g.) and the amount of water absorbed was not related to carcass grade or weight for either the ribeye or *Semitendinosus* muscle. Aging usually increased the water imbibition slightly.

Chemical Composition

Crude Ash. The total ash content of the samples of raw ribeye and *Semitendinosus* muscles varied from 0.77 to 1.32 percent, with most of the values in the range of 0.90 to 1.10 percent. There was some tendency for samples from Good grade and Commercial cow carcasses to show slightly higher ash content than samples from Prime grade carcasses, but differences were much too small to be significant.

Crude Protein (N×6.25). The crude protein content of raw *Longissimus dorsi* and *Semitendinosus* was usually in the range of 20.5 to 23 percent, although values as low as 17.6 percent and as high as 24 percent were observed. Careful inspection of the data does not suggest any apparent relationship between carcass grade or weight and crude protein content. A few extremely high fat samples were low in protein (the low protein sample referred to above contained 26 percent fat).

Total Nitrogen. As the result of cooking losses (drip and evaporation), which will be discussed later, the total nitrogen content of the cooked meat samples varied significantly (table 22, appendix).

When the ribeye data for each year were separately subjected to variance analysis, differences in nitrogen content due to grade, weight, aging, and month sampled were shown to be significant. For the first year's samples and for Good grade samples the second year, the January cooked samples were significantly higher in total nitrogen, particularly after aging. Aging the raw Good grade and Commercial cow cuts increased the nitrogen content of the cooked meat the first year but decreased it the second. For the third year's samples, Prime grade aged, cooked ribeye contained less nitrogen than unaged. Also, the cooked ribeye from August samples, the third year, was lower in nitrogen than samples from the other months. Since these variations, and various weight, grade, aging, and month interactions, were not consistent from year to year, it is not surprising that variance analysis on the combined orthogonic data showed only that cooked ribeye from carcasses of different grades and weights contained significantly different amounts of nitrogen (table 23, appendix). Prime grade cooked ribeye contained significantly less nitrogen than Good grade.

Moisture. The moisture content of the raw samples studied varied from 54.2 to 76.4 percent although most of the values fell in the range of 67 to 73 percent. Usually the *Semitendinosus* contained 1 to 3 percent more moisture than the ribeye from the same carcass, and moisture loss during aging amounted to 1 to 2 percent for most samples. Since moisture content was almost universally inversely related to the intramuscular fat content of raw meat, the influence of grade, weight, and aging on moisture may be seen by considering their influence on intramuscular fat.

Intramuscular Fat. Intramuscular fat in the raw ribeye of the samples studied varied from 1.5 to 26.4 percent, and in the raw *Semitendinosus* from 0.6 to 9.4 percent. There were distinct differences in intramuscular fat due to carcass grade, carcass weight, and the month samples were obtained (table 24, appendix). For the Good grade, heavy carcasses contained significantly more fat in the ribeye than did light carcasses. This was true for Prime carcasses studied the first and third years but not true for the second year. Ribeye from Good grade carcasses obtained in October had a significantly lower percentage of fat than ribeye from Good grade samples obtained in the other sampling periods. This was also true for Commercial cow samples for 2 years out of 3. Ribeye from Prime grade carcasses contained more fat than that from Good grade carcasses. These significant carcass grade and weight differences were also shown by analysis of variance of combined orthogonic data from the first 2 years (table 25, appendix).

The *Semitendinosus* had a lower fat content (about 2 to 5 percent usually) than the raw ribeye from the same carcass.

The data (table 24, appendix) suggest that the ribeye from the 7–8 rib section contained more fat than the ribeye from the 9–12 rib section. Analysis of variance on the data for January and August samples showed that there was no significant difference between the 9–10 and 11–12 rib section (table 25, appendix).

It should be emphasized here that high intramuscular fat values are not necessarily correlated with fatness of the carcass. For example, the ribeye sample containing the highest percentage of fat found in these studies (26.4 percent in the 7–8 rib section) came from a carcass that had no more separable fat than one having a ribeye with 6 percent fat. Observations made during the course of this study show further that high intramuscular fat is not necessarily needed for good "marbling." While it is true that muscle tissue with very high intramuscular fat content (above 10 percent) was universally well "marbled," some samples of lower fat content (4 to 10 percent) were also well "marbled" (fig. 4). These findings emphasize the importance of genetic and feeding studies designed to produce beef animals of high meat quality without excessive amounts of carcass fat.

Nonprotein Nitrogen. This determination was made on all raw and cooked samples the first 2 years. The data for ribeye (table 26, appendix) indicate that the amount of nonprotein nitrogen was influenced by aging and perhaps by others factors. The data for each separate year was subjected to analysis of variance, and it was found that the amount of nonprotein nitrogen did increase very significantly with aging for all groups of carcasses. The increase was greater for the first 2 weeks of aging than for the second 2-week period. For the second year's samples, it was found that Good grade ribeye con-

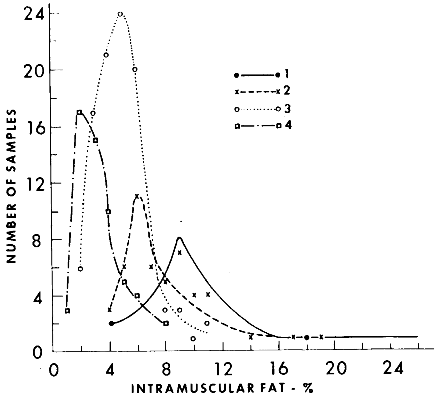

Figure 4.—The number of samples of *Longissimus dorsi* with a given intramuscular fat content for each marbling rating of 1 to 4.

tained significantly more nonprotein nitrogen than did Prime grade ribeye; this was not true for samples studied the first year.

The percentage of nonprotein nitrogen in cooked ribeye was usually slightly greater (0.02 to 0.10 percent) than in raw (table 26, appendix), but the proportion of nitrogen present as nonprotein nitrogen was less because of moisture and fat loss during cooking. Analysis of variance on the data for cooked ribeye showed that cooked aged ribeye contained more nonprotein nitrogen than cooked unaged ribeye. As was the case for the raw samples, cooked Good grade ribeye the second year contained significantly more nonprotein nitrogen than cooked Prime ribeye.

The nonprotein nitrogen content of the *Semitendinosus* was quite comparable to that of the *Longissimus dorsi* and similar aging effects were noted (table 27, appendix).

Differences in nonprotein nitrogen content of meat might be indicative of differences in degree of protein autolysis. Although results reported here are not in agreement with those reported by Wierbicki et al. (*43*), there does appear to be a small but significant increase in nonprotein nitrogen with aging; this would support the belief that protein autolysis does occur during aging. There is no indication from the data presented here that this autolysis is extensive enough to be significant from the standpoint of increasing tenderness during aging. It could be an important factor in flavor change, however, since only small amounts of certain simple peptides would be required for detectable flavor.

Free Amino Nitrogen. Raw meat contained 0.05 to 0.08 percent free amino nitrogen (1 to 2 percent of the total nitrogen present). There was no apparent relationship between carcass grade or weight and the amino nitrogen present in raw meat. Aging usually increased the percentage of amino nitrogen in raw meat (0.01 to 0.02 percent); this change generally was more pronounced in the ribeye than in the *Semitendinosus*. Cooked meat usually contained a slightly lower percentage of its nitrogen as amino nitrogen because a relatively high percentage of this form of nitrogen is contained in the drippings lost during cooking (*14*).

Soluble Protein. Analyses for this nitrogen fraction were made only on samples obtained during the last year of this study. The data (table 28, appendix) do not indicate that the raw meat from the different carcass grades and weights varied appreciably in the amount of soluble protein present. Aging resulted in a decrease of soluble protein in the raw meat and an increase of soluble protein in cooked meat. Cooked unaged ribeye from the lightweight carcasses and Commercial cow carcasses contained less soluble protein than cooked unaged ribeye from heavy carcasses, but this difference disappeared during aging. Analysis of variance on the data for *Longissimus dorsi* showed that all these effects were statistically significant.

Cooked *Semitendinosus* contained less soluble protein than did cooked ribeye, and the increase in soluble protein with aging was not as pronounced for cooked *Semitendinosus* as for cooked *Longissimus dorsi.*

For both raw and cooked ribeye, the samples obtained in January contained significantly more soluble protein than did samples obtained in June or August.

The decrease in the soluble protein in the raw muscle with aging is much greater than can be accounted for by the increase in nonprotein nitrogen with aging. This shows that some simple proteins must be changed to become less soluble with aging. This could occur either by condensation of simple proteins to form larger, less soluble protein complexes or by some change in the physical configuration of the simple protein molecules.

Thus, during aging, under the conditions used in this study, there is not only a breakdown of protein to form nitrogenous substances soluble in 4 percent trichloroacetic acid but there is also a simultaneous change of soluble proteins to proteins not soluble at pH 6.5. The practical significance of these changes is not known at present.

Creatine. Analyses for this compound on samples obtained in the first 2 years of the study showed that raw ribeye varied from 191 mg./100 g. to 431 mg./100 g. However, there was no consistent and significant relation between carcass grade or weight, or extent of aging, and the amount of creatine present (table 29, appendix). Samples obtained in August contained significantly larger amounts of creatine than those obtained in the other sampling periods. Also, the samples obtained the first year were significantly higher in creatine than those obtained during the second year.

The creatine percentage of cooked meat was usually slightly less than that in corresponding raw samples (table 29, appendix). Since considerable amounts of fat and moisture are lost during cooking, the proportion of total nitrogen present in creatine was markedly reduced during cooking. This indicates a considerable loss or change of creatine during broiling. Carcass grade and weight and aging had no consistent significant influence on the creatine content of cooked meat. Cooked ribeye samples obtained in August contained significantly more creatine than those obtained in January.

Raw *Semitendinosus* usually contained slightly more creatine than ribeye from the same carcass. As was the case for ribeye, carcass grade and weight and extent of aging had no consistent, significant influence on the creatine content of the *Semitendinosus* (table 30, appendix). Creatine in the *Semitendinosus* was markedly reduced by cooking. Aged cooked *Semitendinosus* contained more creatine than unaged cooked meat.

Creatinine. As was the case for creatine, creatinine was determined in all samples studied the first 2 years. The creatinine content of the raw meat varied from 8 mg./100 g. to 44 mg./100 g. There was no consistent difference in creatinine content of raw ribeye due to grade of carcass (table 31, appendix). However, analysis of variance of the data showed that aging significantly increased the creatinine content of raw ribeye and that the samples obtained in August were significantly higher in creatinine than those obtained in January. In the Prime grade, the ribeye of heavy carcasses contained more creatinine than the ribeye of light carcasses.

The creatinine content of cooked ribeye was approximately double that of raw ribeye (table 31, appendix). The creatinine content of cooked, aged ribeye was significantly greater than that of unaged, cooked ribeye. As was the case for the raw ribeye, the cooked samples of ribeye obtained in August had more creatinine than those obtained in January. The cooked ribeye from light carcasses contained less creatinine than cooked ribeye from heavy carcasses of the same grade.

The raw *Semitendinosus* contained amounts of creatinine comparable to those found in ribeye, but the increase in creatinine due to cooking was not as pronounced (table 32, appendix). Aging appeared to increase the creatinine content of both raw and cooked *Semitendinosus*, but the number of samples studied was too limited to establish the significance of this relationship.

The increased percentage of creatinine in cooked meat as compared to raw was greater than can be accounted for by the observed drip and evaporation loss during broiling. This, coupled with the observed loss of creatine during cooking, indicates that creatine is changed to creatinine during the broiling process. The possible relationship of these compounds to flavor in cooked meat will be discussed later.

Ammonia Nitrogen. This determination was made only on samples from the first 36 carcasses studied during the first year. Values ranged from 5 to 12 mg. ammonia nitrogen per 100 g. meat and were not consistently related to carcass grade, carcass weight, extent of aging, muscle, or cooking.

Urea Nitrogen. The limited number of analyses for this constituent (samples from 36 carcasses) did not indicate any consistent influence due to carcass grade or weight, aging, muscle, or cooking, although the values obtained ranged from 1 to 21 mg. urea nitrogen per 100 g. meat.

"Volatile" Sulfur. This determination was made only on samples studied during the third year. For heavy Good grade ribeye, the volatile sulfur content was significantly increased by aging; and unaged ribeye from heavy carcasses contained less volatile sulfur than that from light or Commercial cow carcasses (table 33, appendix).

The raw *Semitendinosus* usually contained slightly less (1–2 γ/g.) volatile sulfur than ribeye. During cooking small amounts of volatile sulfur were lost, but cooked meat contained slightly higher percentages of volatile sulfur than corresponding raw samples due to moisture and fat loss during cooking.

Collagen (chemical). Only a limited number of chemical determinations for collagen were made on raw and cooked meat. These ranged from 0.1 to 1 percent collagen. The histochemical determination of collagen on the same samples gave values ranging from 0.5 to 3 percent by volume. Despite this difference in absolute values, the collagen contents of the samples by the two methods were fairly well correlated (fig. 5). Since the chemical method was applied only to a limited number of samples, while the histochemical method was used to determine collagen on all samples, and since the histochemical procedure can be used to indicate distribution as well as amount, discussion of the collagen content of the samples will be included only under the histological section.

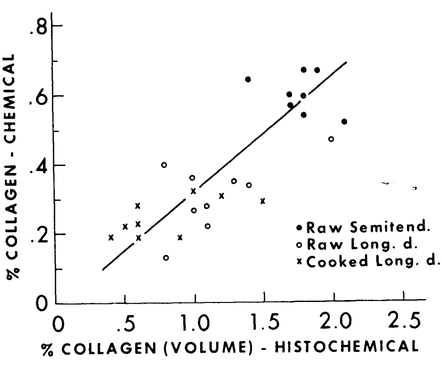

Figure 5.—The relationship between chemical and histological methods of collagen determination on raw and cooked meat.

Extractable Color. For raw ribeye and *Semitendinosus* samples studied during the third year there was no consistently apparent difference in extractable color due to carcass grade, carcass weight, or extent of aging. There was some indication that the ribeye contained slightly more extractable color than *Semitendinosus* from the same carcass. Optical density values for the color extracts ranged from 0.21 to 1.14, with most of the values between 0.5 and 0.8.

The fact that extractable pigment was not related to carcass grade, weight, or extent of aging, while the subjective lean color evaluation was somewhat related, emphasizes the fact that meat color is dependent not only upon the amount of pigment (largely myoglobin) present but also upon its distribution. This would suggest that reflectance measurements on meat at appropriate wavelengths might give a better index of meat color than light absorbancy measurements on extracted pigment solutions.

Histological Properties

Muscle Fiber Diameter. The muscle fiber diameter of samples from 40 of the carcasses studied the first year ranged from 27 to 74 microns. The limited data (table 34, appendix) indicate that muscle tissues from the Commercial cow carcasses had slightly larger muscle fibers than corresponding tissue from younger animals (fig. 6, A and B). Analysis of variance on the data showed that for Prime grade ribeye the muscle fiber diameter was significantly greater in heavy carcasses than in light. There is some indication that this was true also for Good grade carcasses, but the difference shown was

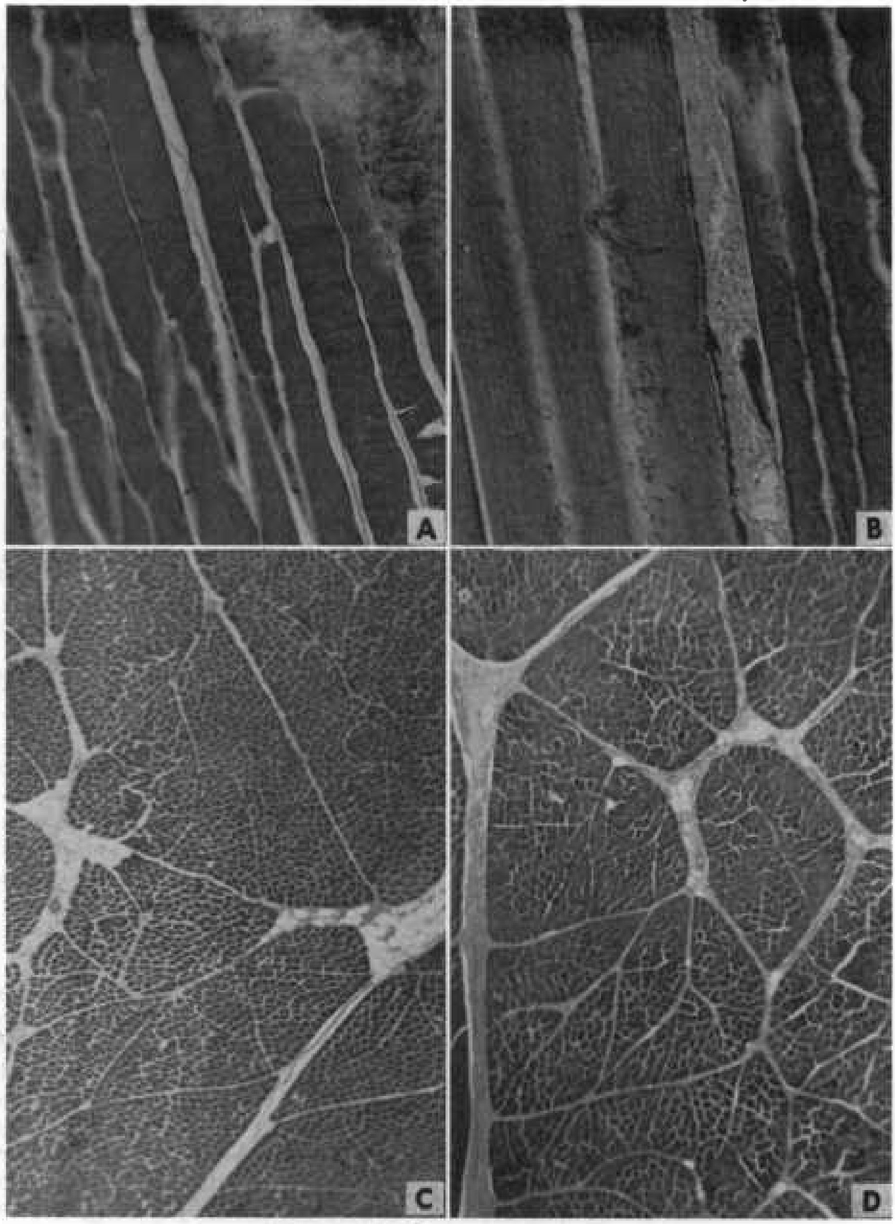

Figure 6.—Relative muscle fiber size and muscle bundle size in *Longissimus dorsi* and *Semitendinosus* from Good and Commercial grade carcasses.

A. (150 ×) Longitudinal section from *Longissimus dorsi* of light Good grade carcass, 4 weeks' aging.

B. (150 ×) Longitudinal section from *Longissimus dorsi* of Commercial cow carcass, unaged. Note larger muscle fibers than in (A).

C. (20 ×) Transverse section from *Longissimus dorsi* of heavy Good grade carcass, unaged.

D. (20 ×) Transverse section from *Semitendinosus* of same carcass as (C). The primary (smallest) muscle bundles are much smaller but more distinct than in (C).

not great enough to be statistically significant. In general, this would agree with findings by Hiner et al. (*21*) who reported that fiber diameter increased with increasing age of the animal.

The fiber diameter in the *Semitendinosus* was greater than in the *Longissimus dorsi* from carcasses of the same grade and weight classification.

The apparent reduction in muscle fiber diameter as the result of aging probably was not truly an aging effect but rather was due to muscle position (p. 35).

Analysis of variance on the data showed further that muscle fiber diameter in ribeye from Good grade carcasses obtained in October was significantly higher than in August, and that for both Prime and Good grade ribeye the fiber diameter was greater in the August samples than in June samples.

Muscle Bundle Size. Primary muscle bundle cross sectional area varied from 0.06 to 0.66 square millimeters in samples from 33 carcasses studied the first year. Secondary muscle bundle area in the same samples varied from 0.26 to 10.7 square millimeters. The data (table 35, appendix) do not indicate that muscle bundle size was related to carcass grade or weight.

Primary muscle bundles were almost always larger, but less distinct, in the ribeye than in the *Semitendinosus* of the same carcass (fig. 6, C and D). This was true also for secondary muscle bundles in samples obtained in August but not for October and January samples (June samples were not examined for this characteristic).

Elastin and Elastic Fiber Diameter. On the basis of histochemical estimation for elastin on samples from 84 carcasses from the first 2 years of this study, elastin content of muscle tissue was not related to carcass grade or weight (table 36, appendix). The elastin content of the *Semitendinosus* was two to five times that of the ribeye from the same carcass. Cooking and/or aging had no detectable effect on the elastin in the meat (fig. 7).

Elastic fiber diameter measurements on samples from 36 carcasses studied the first year showed no relationship between elastic fiber size and carcass grade or weight. Elastic fiber diameter (maximum) ranged from 0.5 to 0.8 microns for ribeye and 3.5 to 6.2 microns for *Semitendinosus.*

Collagen. Results of histochemical estimation of collagen on samples obtained all three years of this study did not show any consistent differences in collagen content of raw or cooked ribeye due to carcass grade or weight (table 37, appendix). The collagen content of raw ribeye was apparently reduced very significantly by aging. However, part of this apparent aging effect must be attributed to differences in collagen content in different parts of the muscle (p. 34). There was a definite loss of collagen during cooking—especially for the unaged ribeye (fig. 8).

The *Semitendinosus* always contained more collagen than the *Longissimus dorsi* from the same carcass but, again, there was no consistent relationship between collagen content of the *Semitendinosus* and carcass grade or weight (table 38, appendix). Aging and/or cooking reduced the collagen content of the *Semitendinosus.*

There was no indication from observations made during this study that the distribution of collagen was consistently different in muscles from carcasses of different grades (fig. 8). Thus, it would appear that the collagen content and distribution in similar muscles from carcasses of different grades are so similar that this cannot generally be of primary importance in determining organoleptic differences between grades.

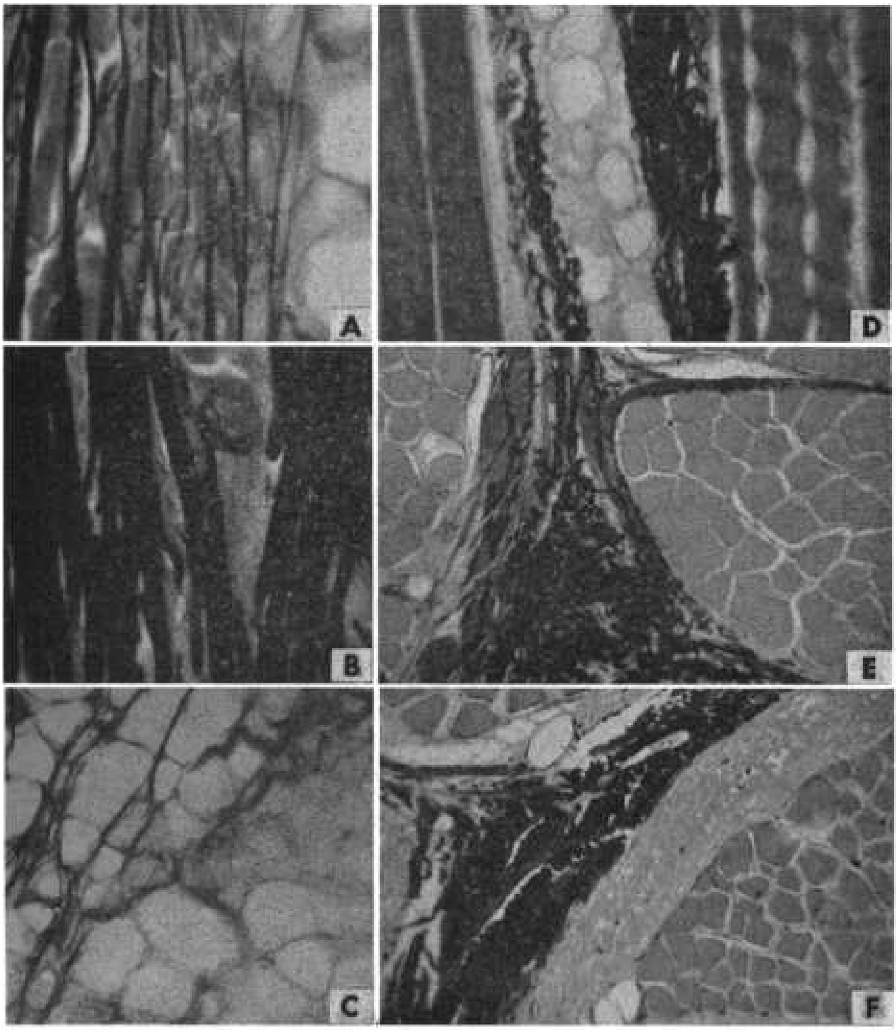

Figure 7.—Size (diameter) and loci of elastin fibers and the influence of aging and cooking on elastin.

A. (320 ×) Longitudinal section from raw *Longissimus dorsi* of light Prime grade carcass, unaged.
B. (320 ×) Longitudinal section from raw *Semitendinosus* of light Good grade carcass, 2 weeks' aging. Note much greater diameter of elastic fibers than in (A), reflecting primarily a difference in the two muscles.
C. (150 ×) Section from raw *Longissimus dorsi* of heavy Prime grade carcass, 4 weeks' aging, showing an unusual distribution of elastic fibers through the fat cells in contrast to the usual loci of elastin shown in (A) ahd (B).
D. (150 ×) Longitudinal section from raw *Semitendinosus* of Commercial cow carcass, unaged, showing a perimysium with typical collagen, fat and elastin distribution.
E. (150 ×) Transverse section from cooked *Semitendinosus* of light Good grade carcass, unaged, showing a triangular perimysium with elastic fibers intact, distinct and apparently unaffected by cooking (grayish background is collagen).
F. (150 ×) Transverse section from cooked *Semitendinosus* of same carcass as (E) after 2 weeks' aging, showing distinct, intact elastic fibers with no evidence of any change induced by aging or cooking (grayish areas contain collagen degraded by aging and cooking).

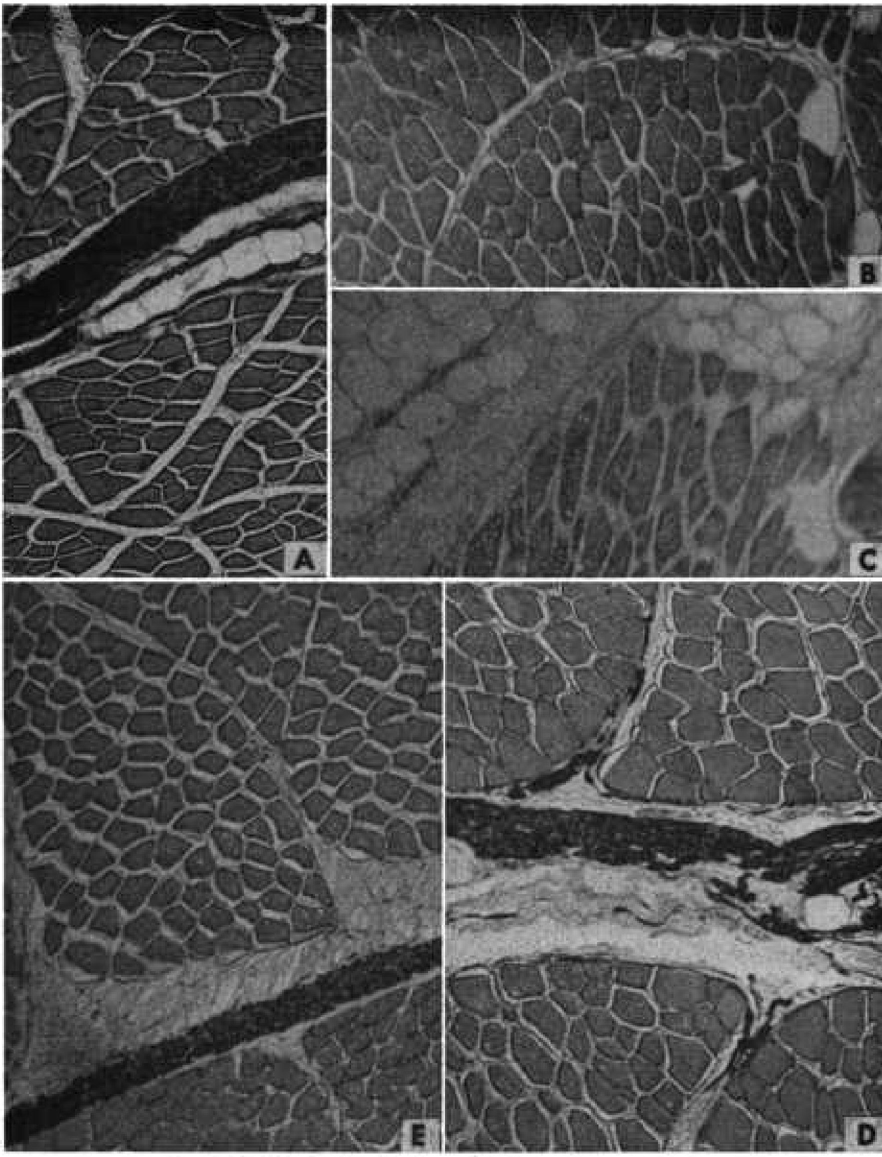

Figure 8.—The collagen of beef muscles as related to carcass grade and influence of aging and cooking.

A. (150 X) Transverse section from raw *Longissimus dorsi* of heavy Good grade carcass, unaged, showing intact collagenous fibers in a perimysium.

B. (150 X) Transverse section from cooked *Longissimus dorsi* of light Prime grade carcass, unaged, showing collagen degraded by cooking (upper left and lower right).

C. (150 X) Transverse section from same muscle, cooked, from the same carcass but after 2 weeks' aging, showing increased collagen degradation due to the combined effect of aging and cooking.

D. (150 X) Transverse section from raw *Longissimus dorsi* of light Good grade carcass, unaged, showing some collagen degradation.

E. (150 X) Transverse section from cooked *Semitendinosus* of light Prime grade carcass, 2 weeks' aging (same carcass as (C), showing less collagen degradation by aging and cooking than was the case for the *Longissimus dorsi*.

It is interesting to note that raw meat containing relatively large amounts of collagen lost more collagen during cooking than did meat in which the collagen content was already low. If high collagen content of cooked meat contributes to toughness, then this effect might be overcome *either* by collagen hydrolysis before cooking (aging), or by using a cooking procedure designed to bring about extensive collagen hydrolysis. However, since extended aging (4 weeks) did not reduce the collagen content of *Semitendinosus* to a level comparable to that in ribeye, the importance of a collagen-degrading method of cooking for this muscle is obvious.

Endomysial, Perimysial, and Total Fat. These histological determinations for fat, as classified above, were made on samples from most of the carcasses studied the first two years. The amount and distribution of fat varied in the different grades, weights and muscles studied (fig. 9). Usually, 95 percent or more of the total intercellular fat was present as perimysial fat. Samples high in perimysial fat also contained high amounts of endomysial fat. Since there is no indication that carcass grade and weight relationships were different on the basis of endomysial, perimysial, and total fat (determined histologically) than on the basis of "linear" fat and intramuscular fat, no discussion of these results needs to be given here.

"Linear" Fat. "Linear" fat levels, determined histologically on samples from all carcasses studied, varied from 1 to 101 mm./150 mm^2. The data (table 39, appendix) indicate that ribeye of heavy carcasses contained more "linear" fat than that of light carcasses of the same grade and that the anterior portion of the ribeye contained more "linear" fat than the posterior portion. Because of large, inconsistent variations in results, however, the only statistically significant difference was that ribeye from light Good grade carcasses contained less "linear" fat than ribeye from the other grades and weights.

The *Semitendinosus* had a lower "linear" fat level than the *Longissimus dorsi* from similar carcasses, and the top portion of the *Semitendinosus* had less "linear" fat than the middle and bottom portions.

These results agree in general with the total intramuscular fat determinations (chemical) and the marbling ratings. However, the extremely variable and somewhat inconsistent values for "linear" fat make results difficult to evaluate. This suggests that the amount and distribution of fat at different locations in a muscle vary greatly (fig. 10C). If it were possible to examine a large number of sections from different locations in a muscle, the "linear" fat values obtained should give a good indication of the amount and distribution of fat. Unfortunately, this would be so time consuming that it is almost impossible from any practical viewpoint.

Liposomes. Studies on 27 carcasses showed that liposomes (intracellular fat) were present in some samples but not in others (fig. 10E). Their occurence apparently was not related to carcass grade, carcass weight, muscle, or extent of aging.

Fat Dispersion by Cooking. During cooking, fat was released from the intercellular fat cells and was found dispersed in small droplets in perimysial areas where collagen hydrolysis had occurred (fig. 10D). The greater the distance from the original fat cells, the smaller were the dispersed fat droplets. On the basis of the limited data available, this fat dispersion pattern apparently was not related to carcass grade or weight. It was noticeably greater in ribeye than in *Semitendinosus*, and appeared to be greater in fresh meat than in aged.

A detailed discussion of these results and their possible significance has been given by Wang et al. (*41*).

Muscle Fiber "Erosion" by Cooking. During broiling of steaks the muscle fibers become roughened or "eroded" (fig. 10). This phenomenon was apparently not related to carcass grade or weight or extent of aging and was quite generally observed. It was limited to the surface of the muscle fibers and was, therefore, distinctly different from the typical autolytic breaks due to aging (fig. 10B).

Muscle Fiber Autolysis. Fiber autolysis on the samples studied over the 3-year period varied from 0 to 4 on an arbitrary subjective rating scale. For Prime grade ribeye, autolysis ratings were higher for light carcasses but the reverse was true for Good grade (table 40, appendix). Aging apparently increased the autolysis rating for ribeye from all grades and weights (fig. 11); this autolysis was greater during the first 2 weeks' aging period than during the second 2-week period. Although these differences were all statistically significant, the observed aging effect was undoubtedly due in part to the difference in autolysis levels at different positions in the muscle (p. 34).

Autolysis in the *Semitendinosus* was much less extensive than in the *Longissimus dorsi*, and the influence of aging was much less pronounced. There were no evident relationships between either grade or weight and autolysis in the *Semitendinosus*.

Autolytic breaks in muscle fibers were usually observed even in samples obtained immediately after the carcasses were chilled (24 to 48 hours after slaughter). These breaks appeared as irregular areas within the sarcolemma that usually contained some granular material (fig. 9F). As the meat was aged, additional breaks were usually observed, and the areas containing granular material increased in size. This increase was apparently caused by additional autolysis and by shrinkage of the fibrils within the muscle fiber.

It should be emphasized that the sarcolemma, the envelope enclosing each muscle fiber, was not broken by the autolytic changes occuring in the tissue. Since the tenderizing effect of aging is not quantitatively related to the extent of autolysis (to be discussed later), it could be inferred that characteristics of the sarcolemma may contribute to differences in tenderness of meat. Careful consideration should be given to this possiblity in any extensive future study of meat tenderness and factors influencing it.

Extensibility of Muscle Fibers. This determination was made on samples from 15 carcasses studied the last sampling period of the third year. From the limited amount of data it appears that fresh raw ribeye from heavier animals had more extensible fibers than ribeye from lightweight animals. Fibers from fresh raw *Semitendinosus* were more extensible than those from ribeye. Aging reduced the extensibility. Fibers from cooked meat were more extensible than those from corresponding raw samples.

This study with a discussion of its possible significance from a practical standpoint has been reported in detail by Wang et al. (*42*).

Cooking Losses and Organoleptic Ratings on Cooked Beef

Drip Loss During Broiling. The drip loss in rib steaks during broiling was related to carcass grade and weight, month the samples were obtained, and the extent of aging or rib position from which the steaks were cut (table 41, appendix). The drip loss of rib steaks from Good grade carcasses was significantly less than that of steaks from Commercial cow or Prime grade carcasses. Within each grade, the drip loss was less in steaks from light carcasses than in steaks from heavy

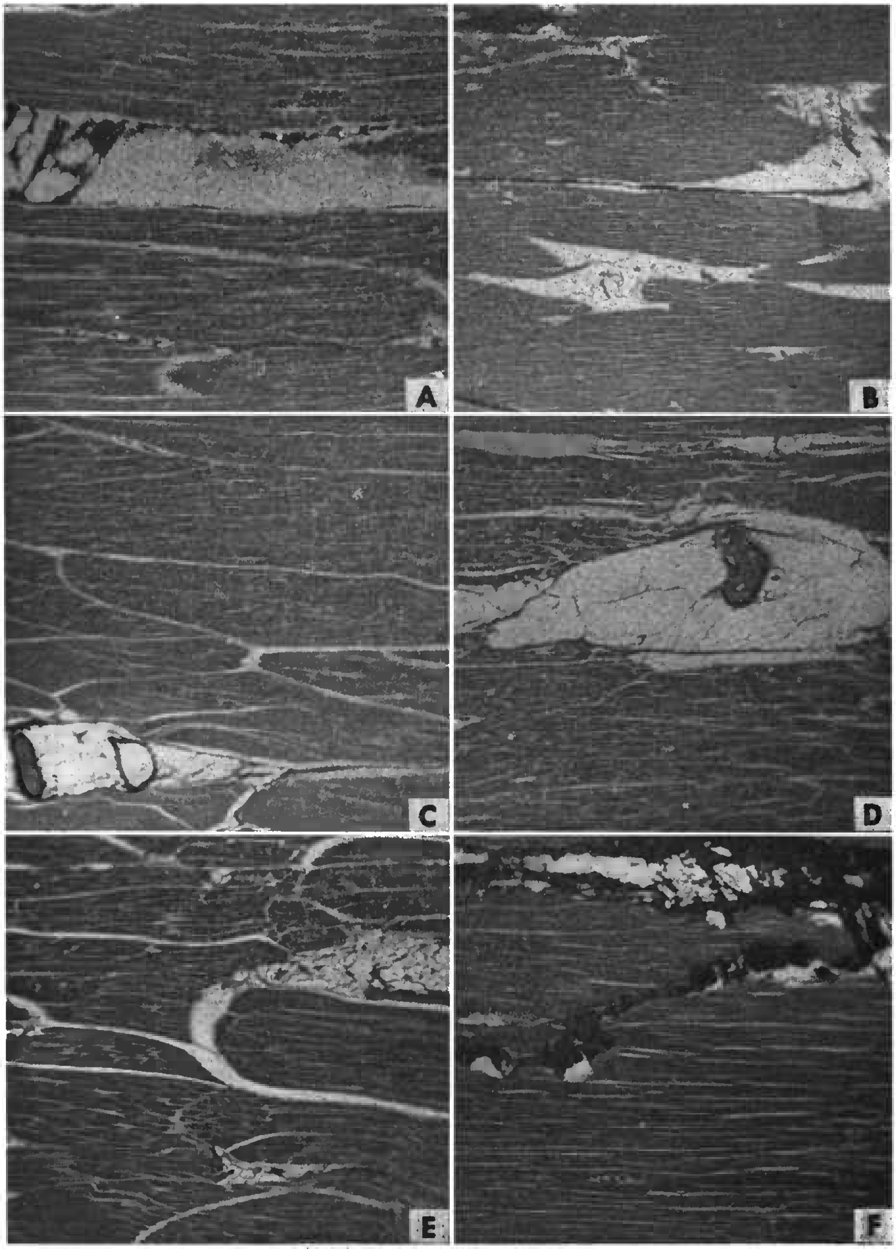

Figure 9.—Fat content and distribution typical in muscles from carcasses of different grades and weights. (All photomicrographs are of longitudinal sections at a magnification of 12 X).

A. *Longissimus dorsi* of light Prime grade carcass.
B. *Longissimus dorsi* of heavy Prime grade carcass.
C. *Longissimus dorsi* of light Good grade carcass.
D. *Longissimus dorsi* of heavy Good grade carcass.
E. *Longissimus dorsi* of Commercial cow carcass.
F. *Semitendinosus* of heavy Prime grade carcass (same carcass as B).

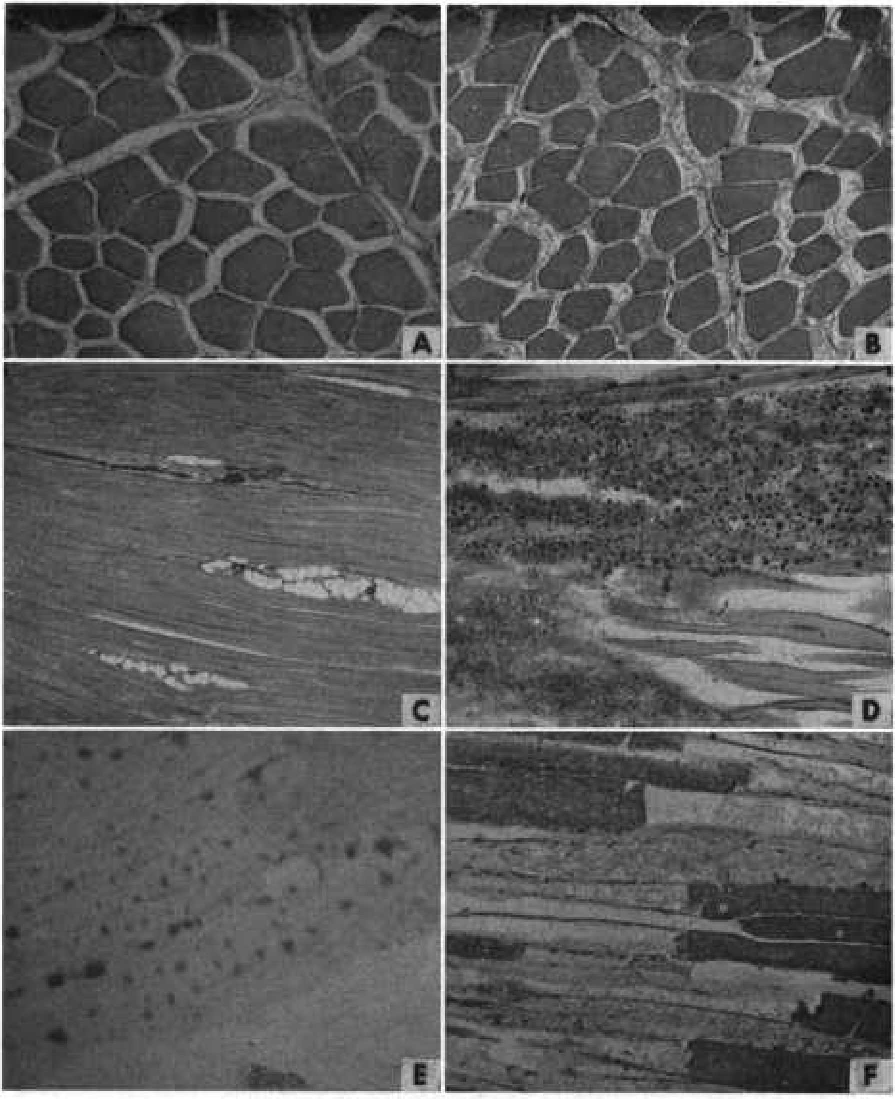

Figure 10.—Fat distribution and the influence of aging and cooking on some components of muscle tissue.

A. (150 X) Transverse section from raw *Longissimus dorsi* of heavy Prime grade carcass, unaged.

B. (150 X) Transverse section, same as (A) but cooked, showing degraded collagenous material in the endomysial spaces and "erosion" of the muscle fibers. Both changes result from cooking.

C. (25 X) Longitudinal section from raw *Longissimus dorsi* of Commercial cow carcass, unaged, showing small "linear" deposits of fat. These deposits are too small to be seen without magnifications and would not therefore constitute "marbling."

D. (75 X) Section from cooked *Longissimus dorsi* of light Good grade carcass, unaged, showing minute fat droplets dispersed from a perimysial fat deposit throughout areas of degraded collagen (grayish background).

E. (320 X) Section from raw *Longissimus dorsi* of light Good grade carcass, unaged, showing liposomes in the muscle fibers.

F. (75 X) Longitudinal section from raw *Longissimus dorsi* of light Good grade carcass, 2 weeks' aging, showing the sarcolemma apparently intact even in the portions of the fibers that have undergo·

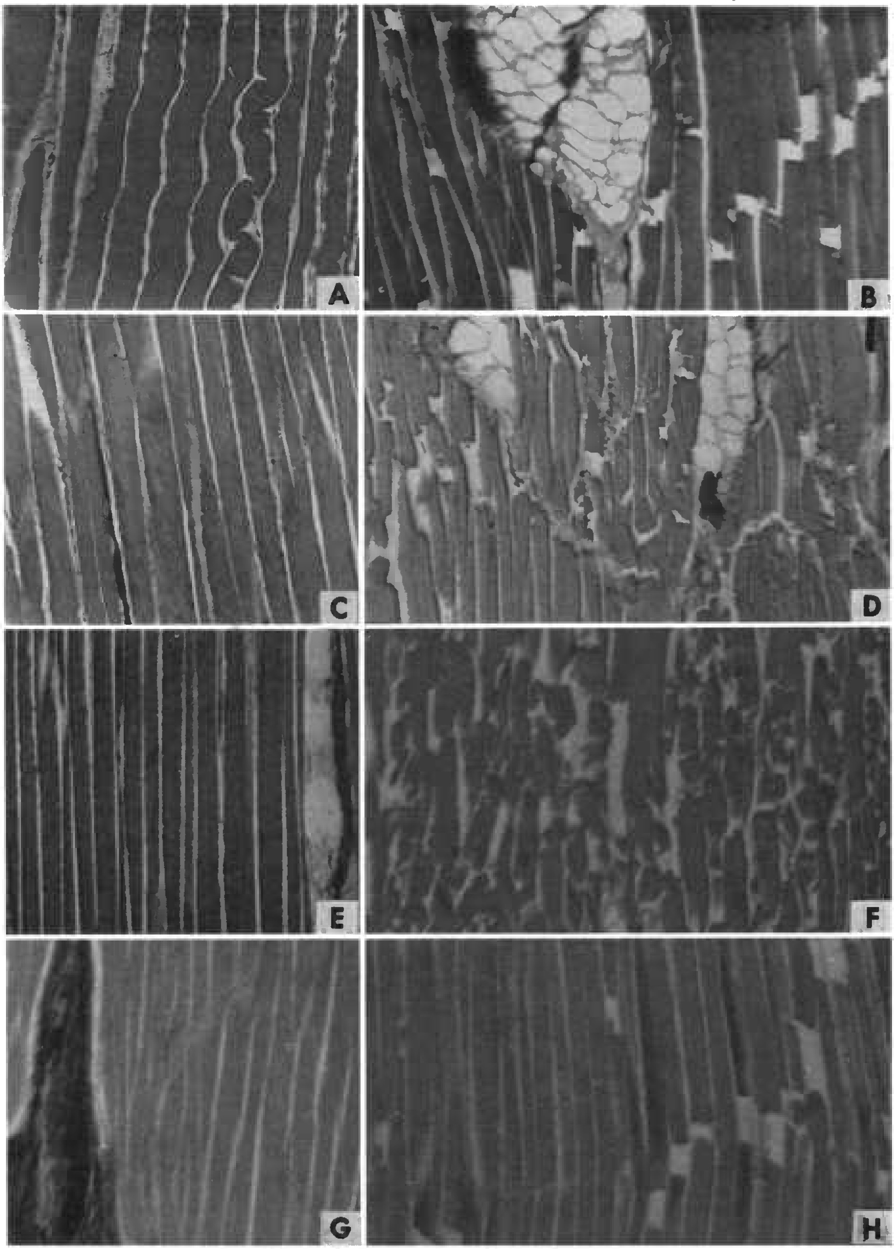

Figure 11.—Autolysis of muscle fibers from carcasses of different grades. (All longitudinal sections.)

A. (75 X) Section from raw *Longissimus dorsi* of heavy Prime carcass, unaged.
B. (50 X) Same as (A) except 2 weeks aged.
C. (75 X) Section from raw *Longissimus dorsi* of heavy Good grade carcass, unaged.
D. (50 X) Same as (C) except 2 weeks aged.
E. (50 X) Section from raw *Longissimus dorsi* of Commercial cow carcass, unaged.
F. (50 X) Same as (E) except 2 weeks aged.
G. (50 X) Section from raw *Semitendinosus* of light Good grade carcass, unaged.
H. (50 X) Same as (G) escept 2 weeks aged.

carcasses. The data indicate that regardless of carcass grade and weight, aged rib steaks had less drip loss than unaged steaks. However, this is probably due to the location from which the steaks were taken because the drip loss from unaged steaks taken from the posterior end of the rib cut was significantly greater than the drip loss of steaks taken from the anterior end. Drip loss in rib steaks from carcasses sampled in January was greater than that in rib steaks sampled in August. Drip losses were highest in steaks studied the third year and lowest in steaks studied the first year. Analysis of variance on each year's data, and on combined orthogonic data for the 3 years (table 42, appendix), showed that the differences in drip loss outlined above were all statistically significant.

The limited data on steaks from the round show that drip loss in the unaged steaks was somewhat less than in rib steaks, especially for Commercial cow and Prime grade carcasses (table 41, appendix). Aging the round for 2 weeks appeared to increase the drip loss in round steaks but, as was the case for rib steaks, it is probable that this is a reflection of the position from which the steaks were cut rather than a true aging effect. This seems particularly likely since the apparent aging effect on drip loss was reversed for rib steaks and round steaks.

Since the drippings from broiled steaks are largely fat, the amount of drip loss depends to a large extent on the proportion of fat present in the raw steak. The intermuscular and external fat especially are apt to be lost in the drippings. Thus, the differences in drip loss due to carcass grade and weight, and positions from which the steaks were cut, probably reflect the proportion of fat that was present in the raw steak. In this connection, it is interesting to note that grade differences with respect to drip loss of rib steaks are in complete agreement with separable carcass fat figures calculated from the separable fat of the 9–10 rib section. This was true also for the difference observed for month sampled; that is, carcasses sampled in January were fatter than those of the same grade sampled in August.

Studies on the nitrogenous components on the drippings have been reported previously (*14*) and showed that only a very small proportion (2 to 2.5 percent) of the total nitrogen present in the raw steaks was found in the drippings after broiling. This was essentially all nonprotein nitrogen and about 20 percent of it was free amino nitrogen. Grade and aging had no detectable influence on the amount or composition of nitrogenous compounds present in the drippings after broiling.

Evaporation Loss During Broiling. Carcass grade and weight and the extent of aging influenced the amount of evaporation from rib steaks during broiling (table 43, appendix). Loss by evaporation was greater for rib steaks from light Good grade carcasses than for rib steaks from other carcass grades or weights. Aging for 2 weeks appeared to increase evaporation losses during broiling but, as was the case for drip loss, this effect was probably due in part to position from which the steaks were taken. Evaporation loss by steaks studied the third year was greater than that for steaks studied the first 2 years. Analysis of variance on each individual year's data and on the combined 3 years' orthogonic data (table 44, appendix) showed that all these differences in evaporation loss were statistically significant.

Among carcasses of the same grade and weight, steaks cut from the round had much greater evaporation loss during broiling than did rib steaks. Round steak from Commercial cow carcasses lost more by

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evaporation during broiling than did round steaks from other groups of carcasses (table 43, appendix). Although differences in evaporation loss due to aging the round were found, the differences were not consistent enough for definite conclusions to be drawn.

In general, there was a close inverse relationship between evaporation loss and drip loss during broiling; that is those samples showing high drip loss showed low evaporation loss, and *vice versa.* This would support the view that drip and evaporation losses are dependent on the fat and moisture content, respectively, since the moisture and fat contents of meat are inversely related. Other factors are undoubtedly effective, however, as indicated by the fact that total broiling losses in aged steaks, particularly after 4 weeks' aging, were less than total broiling losses in unaged steaks.

Aroma of Broiled Steaks. Practically all of the aroma scores for the broiled steaks were between 6 and 8 on the 10-point rating scale used. There was no indication from the ratings that aroma was related to carcass grade or weight. The few steaks that were scored 5 in aroma were from Good grade or Commercial cow carcasses. The data showed a slight tendency for aged steaks, especially after 2 weeks' aging, to be scored higher in aroma than unaged steaks. This was not pronounced nor consistent enough to be significant.

Broiled round steaks were comparable in aroma to broiled rib steaks. In a few cases unaged round steak was scored slightly lower in aroma than rib steak from the same carcass, but the difference always disappeared during aging.

Flavor of Fat in Rib Steaks. Little difference in flavor of fat due to carcass grade or weight was found. Most scores were between 6 and 8. There was some tendency for fat flavor to improve with aging, especially during the first 2 weeks. Flavor of fat in Good grade and Commercial cow steaks frequently became less desirable in the 2 to 4 week aging period.

Lean Flavor. The scores for lean flavor of the broiled ribeye samples ranged from 5.2 to 9 and those for broiled *Semitendinosus* ranged from 3.5 to 7.7. The standard error of the mean for the scores of the individual judges on the same sample usually did not exceed 0.6. There were pronounced differences in lean flavor scores due to carcass grade, weight and extent of aging (table 45, appendix). For all 3 years of the study, Prime grade ribeye had significantly better lean flavor than ribeye from Good grade. Aging the rib cut for 2 weeks effected a pronounced improvement in the flavor of the broiled ribeye from all carcasses. An additional 2 weeks' aging period usually resulted in a significant reduction in lean flavor score for broiled ribeye from Good grade and Commercial cow carcasses, but the lean flavor of ribeye from Prime grade carcasses was usually increased or unaffected. In the Good grade, broiled unaged ribeye from heavy carcasses had a better lean flavor than that from light carcases, but the difference was less pronounced in the aged samples. Analysis of variance on the combined orthogonic data for the 3 years (table 46, appendix) shows that the aging effect on lean flavor of the August samples was more pronounced than on the January samples. October and June samples resembled the August samples in this respect. Samples obtained the second year of the study were given significantly lower lean flavor scores than those studied the first and third years.

For the broiled *Semitendinosus*, the limited data from the last 2 years of the study do not indicate any pronounced differences in lean flavor due to carcass grade or weight (table 45, appendix). Lean flavor scores for this muscle were lower than those for ribeye, especially in Prime grade carcasses. As was the case for ribeye, aging the round for 2 weeks improved the lean flavor of broiled *Semitendinosus*, but aging for an additional 2 weeks usually had an adverse effect on the lean flavor.

Tenderness. Panel scores for tenderness of broiled ribeye ranged from 2.2 to 9.3, and those for tenderness of *Semitendinosus* ranged from 3.0 to 8.2. Standard error of the mean for the scores of individual judges on the same sample usually did not exceed 0.7. Tenderness of the *Longissimus dorsi* from broiled rib steaks was associated with carcass grade and weight and extent of aging (table 47, appendix). Analysis of variance on each separate year's data and on the combined orthogonic data for the 3 years (table 48, appendix) showed that the ribeye from Prime grade carcasses was more tender than that from Good grade or Commercial cow carcasses. Aging, especially for the first 2-week period, improved tenderness of the broiled ribeye. The influence of aging on tenderness was much more pronounced on ribeye from Good grade carcasses, especially lightweight Good, than on ribeye from Prime grade carcasses. The effect of aging on ribeye tenderness was least pronounced in heavy Prime carcasses. Although the difference was not great enough to be statistically significant, the tenderness of ribeye samples obtained in June was less influenced by aging than samples obtained the other sampling periods.

The *Semitendinosus* from broiled unaged round steak was less tender than broiled ribeye from carcasses of the same grade and weight (table 47, appendix). As was the case for ribeye, aging the round increased the tenderness of the *Semitendinosus* from broiled round steak. *Semitendinosus* from broiled steak from unaged round of Commercial cow was less tender than that from rounds of the other carcass groups studied. This difference disappeared after aging.

Since tenderness is such an important feature of meat from the consumer standpoint it is particularly important to emphasize here that for unaged meat the ribeye and *Semitendinosus* from Prime grade carcasses were more tender than those from Good grade. For aged meat, the difference in tenderness of the Prime and Good grades was not nearly so pronounced. Since most meat sold in the retail market is not aged, except incidental to the time required for distribution, the grade probably reflects an actual difference in tenderness between Prime and Good grades, as observed by the consumer.

Juiciness. Juiciness scores for cooked *Longissimus dorsi* varied from 4.3 to 9 and from 3.7 to 8 for cooked *Semitendinosus.* Prime grade ribeye was usually slightly more juicy than Good grade ribeye (table 49, appendix), and for the first 2 years of the study this difference was statistically significant. For all 3 years of the study, heavy Good grade ribeye was more juicy than ribeye from light Good grade carcasses. Aged ribeye was sometimes more juicy than unaged ribeye, but this effect was not great enough nor consistent enough to be statistically significant except for samples studied the first year. Analysis of variance on the combined 3 years' orthogonic data (table 50, appendix) showed only that ribeye from light Good grade carcasses was less juicy than that from carcasses of the other grade and weight classifications.

Broiled *Semitendinosus* was less juicy than broiled ribeye (table 49, appendix) but there were no consistent, pronounced differences due to carcass grade, weight, or extent of aging.

Biochemical Properties of Beef

During the course of these studies the activity of certain oxidative enzyme systems in beef-muscle tissue was investigated. The results of these investigations have been reported previously (*1*, *26*, *27*) and are reviewed briefly here.

Adenosinetriphosphatase, succinic dehydrogenase, and the glycolytic system showed no reduction in activity in intact beef muscle (*Longissimus dorsi* and *Semitendinosus*) during the 4-week aging period. However, aldolase activity dropped about 30 percent during the first 2-week aging period and an additional 20 percent during the 2 to 4 weeks' aging at 35° F. The glycogen content of the muscle was low (about 1 mg. per gram) at the time the samples were received and did not change during the 4-week aging period. Thus it appears that lack of available substrate (i.e., glycogen and oxygen) rather than the instability of the specific enzyme systems is the limiting factor in the metabolism of intact muscle tissue after the animal is killed. It is important also to note that variations in carcass grade or weight were not related to the carbohydrate metabolism of the muscle from the time the samples were received (48 hours after slaughter) to the end of a 4-week aging period.

Intramuscular Variations

The sampling plan outlined in the experimental procedure involved taking samples of ribeye from the 11–12 rib section 24 to 28 hours after slaughter, samples from the 9–10 rib section at 2 weeks, and samples from the 7–8 rib section at 4 weeks. This appeared to be the only practical method for sampling after aging in the cut. However, it was recognized that variations within the muscle from the posterior to the anterior portion of the rib cut might well complicate interpretation of the results on the influence of aging. To determine if this intramusclar variation was great enough to influence the interpretation of results, unaged ribeye from 21 carcasses was sampled at all positions.

The data from the raw samples (table 51, appendix) show that there were some distinct differences in characteristics of *Longissimus dorsi* from one end of the rib cut to the other. These differences were not great and were not detected in every carcass studied. In general, however, the posterior portion of the ribeye had higher shear strength and contained less fat but more collagen than the anterior portion. For Good and Commercial cow grade carcasses the posterior end of the ribeye had a lower specific conductance and lower autolysis rating than the 7–8 rib section. In broiled ribeye from the same carcasses (left side), the posterior end generally had higher specific conductance, more collagen, and lower scores for lean flavor and tenderness (table 52, appendix).

Unfortunately, these differences in intramuscular properties of the ribeye are such that they do affect interpretation of results on the influence of aging. On the basis of these intramuscular variations it appears likely that the reported (p. 13) nonsignificant decrease in shear strength of raw ribeye with aging was entirely a position effect and was *not* the result of aging. Similarly, the suggested aging effect on specific conductance of raw and cooked ribeye (p. 14) is probably only a muscle-position effect. The apparent reduction in collagen and the apparent increase in autolysis rating by aging (p. 23 and p. 28) must be attributed in part to muscle position and not entirely to the influence of aging. The observed improvement of tenderness with aging was much greater than can be accounted for by muscle-position effect and must, therefore, be considered largely due to the influence of aging.

Since the right ribeye was used for raw samples and the left ribeye for cooked samples, it was important to determine whether or not there was enough difference between right and left sides of the carcass to make cooking effects difficult to establish. The data on four carcasses (table 53, appendix) show that ribeye from the same position on the two sides of the carcass did not have exactly the same composition and properties. However, the differences were not great, in most cases, and were not consistent—that is, the right side was neither consistently higher nor lower in a given component than the left.

These results on the influence of position on muscle composition and properties should be of great value in planning for any future work on meat quality. Essentially, the data show that the most reproducible samples can be obtained from immediately adjacent sections of the *Longissimus dorsi.* Fairly satisfactory reproducibility can be expected between samples taken from right and left sides of the carcass at similar muscle positions. Samples taken from the *Longissimus dorsi* at considerable distance from each other may be greatly different in properties, which will make it difficult to distinguish between the influence of treatment and the influence of muscle position on any muscle characteristic under investigation. If it is possible to do so, complete randomization of samples with respect to muscle position, as used in experiments described by Harrison et al. (19), should be used.

The statements made above with respect to the *Longissimus dorsi* apply generally to the *Semitendinosus.* Although much more limited data were obtained on the *Semitendinosus* in this study, it appears certain that the center portion of the *Semitendinosus* contained more fat, exhibited a greater autolysis level, and had a lower raw shear strength than did either end. The muscle fiber diameter in the *Semitendinosus* decreased progressively from top to botom. Despite the quantitative differences in characteristics between muscles and within the same muscle, the characteristics of the two muscles were fairly well correlated (table 4). The fat content and specific conductance of the two muscles were very significantly correlated. The tenderness scores of fresh meat and the juiciness scores of meat aged

TABLE 4.—*Correlation coefficients between certain characteristics of the* Longissimus dorsi *and* Semitendinosus *muscles*

	No aging		2-week aging		4-week aging	
	Number of observations	r	Number of observations	r	Number of observations	r
Tenderness, cooked	23	**0.5060	22	*0.4238	14	0.1957
Juiciness, cooked	23	.1848	22	.0761	14	*.5219
Collagen, raw	39	.1517	39	.0038	27	.0682
Intramuscular fat, raw	39	**.8359	38	**.7002	26	**.7669
Linear fat, raw	35	.2583	23	**.7529	14	**.7060
Specific conductance, raw.	39	*.3747	39	*.4743	27	**.6448

*Significant at 5 percent level.
**Significant at 1 percent level.

4 weeks also were significantly correlated for the two muscles, but the collagen contents of the two muscles were not correlated.

Relationships of Certain Physical, Chemical, and Histological Properties of Beef to its Organoleptic Characteristics

Previous investigations (*2*, *21*, *22*, *23*, *25*, *28*, *39*, *44*), practical observations, and the data obtained in this study have indicated that organoleptic quality of cooked meat is associated with certain physical, chemical, and histological properties (fat content, collagen content, color, amount of autolysis, etc.). For each group of samples investigated in the course of this study, correlation coefficients were determined for many of the meat characteristics to establish the quantitative level of these indicated relationships. Where significant relationships were indicated for several separate periods, correlation studies were made on each year's combined data. The results of these correlation studies are discussed below. Unless otherwise indicated, the discussion applies only to *Longissimus dorsi*.

Tenderness. Several factors were shown to be significantly associated with tenderness (table 54, appendix). Shear strength of cooked meat was a good index of tenderness. This was particularly true for unaged meat. The fact that the negative correlation coefficients between shear strength and tenderness of aged cooked meat were lower than those for unaged meat is readily explainable when one recognizes that the tenderness scores (and shear values) for aged meat are included in a very narrow range. Thus, unavoidable experimental errors contribute a much greater part of the observed variations, and the apparent correlation is reduced accordingly. This same situation exists for all other properties that may be associated with tenderness.

Although Deatherage and Garnatz (*9*) have indicated that the relationship between tenderness score and shear value for cooked meat is not sufficiently close to justify using shear strength as a reliable index of tenderness, other investigators (*4*, *17*, *33*, *34*) have reported the same close relationship found in these studies. It would appear, therefore, that this objective method for tenderness evaluation would be satisfactory for most meat-quality studies.

Tenderness of the cooked unaged ribeye was closely correlated with the fatness of the carcass and the amount of intramuscular fat in samples studied the first 2 years. However, the correlation between "linear" fat and tenderness was not as good despite the fact that for several individual sampling periods the correlation between "linear" fat and tenderness was quite high. The subjective marbling rating also showed a very significant correlation with tenderness for samples studied the second year. These fat-tenderness relationships were less pronounced or absent in aged meat. This is understandable because aging increases the tenderness of low-fat meat disproportionately faster than high-fat meat. Thus, in aged meat, factors other than fat are responsible for differences in tenderness, and there was little correlation between fat content and tenderness. From a practical standpoint, the implications of these findings are extremely important. Since most meat sold at retail reaches the consumer in 7 to 10 days after slaughter, aging effects on tenderness will be quite limited within carcasses of similar maturity, and an adequate amount of well-distributed marbling will be indicative of tenderness. Very lean, poorly marbled meat would be, in general, less tender.

Except for unaged samples studied the second year, fiber autolysis was not significantly related to tenderness. It would appear, therefore, that fiber autolysis is not necessarily associated with tenderness.

These studies showed that tenderness was only slightly correlated (negatively) with the collagen content of raw or cooked meat. However, it is perhaps significant that, with two exceptions, all correlation coefficients between collagen content of the meat and tenderness were negative. Thus, it may be concluded that collagen content of the ribeye was probably a minor factor contributing to toughness. For lower grades of meat, or less tender cuts, the collagen content might be a much more important factor. Also, the nature of the fat dispersion into collagenous tissue during cooking, as described by Wang et al. (*41*), may be more important than collagen content per se.

For unaged ribeye, specific conductance of the raw meat was significantly correlated with tenderness for 2 of the 3 years studied. For aged ribeye, the specific conductance was usually negatively correlated, but not significantly, with tenderness. There is no very obvious explanation for this apparent relationship. Since tenderness is closely associated with fat content, one might expect tenderness to be *inversely* correlated with conductance because fat has a higher electrical resistance than lean. The direct relationship reported above, and previously reported by other investigators (*15*, *32*), can only indicate that the particular organization and properties of meat that are associated with tenderness also contribute to low electrical resistance. Perhaps this is associated with cell membrane (sarcolemma) characteristics, or with the particular distribution of inorganic ions which influences the degree of hydration and other properties of the meat protein, as suggested by Wierbicki et al. (*44*).

Lean color of the raw ribeye was significantly correlated with tenderness of unaged samples studied during the last 2 years of this investigation. The same correlation was indicated for unaged samples studied the first year, and for all aged samples, but was not statistically significant. Again, there does not seem to be any good theoretical explanation for this relationship. However, the results do confirm the generally accepted practical belief that a bright lean color gives some indication of tenderness.

Penetrometer readings on raw ribeye were negatively but nonsignificantly correlated with tenderness of cooked ribeye. This would indicate that tenderness of cooked meat is only slightly influenced by the ease with which fibers of the raw meat can be separated.

Wang et al. (*42*), on the basis of limited data obtained during the third year of this investigation, have suggested that the extensibility of muscle fibers from cooked meat may be related to tenderness in some grades of cracasses. Additional studies are needed before the significance of these findings can be elaborated. Other characteristics of the ribeye (shear values for raw meat, penetrometer readings on cooked meat, firmness readings, etc.) were apparently not related to tenderness.

Juiciness. As was the case for tenderness scores, panel scores for juiciness were very significantly correlated with carcass fat, intramuscular fat, and marbling (table 55, appendix). Actually, the relationship between juiciness and intramuscular fat is curvilinear rather than linear (fig. 12). Intermuscular fat levels above 8 percent have little or no effect in terms of increased juiciness of cooked meat.

The panel scores for juiciness were remarkably well correlated

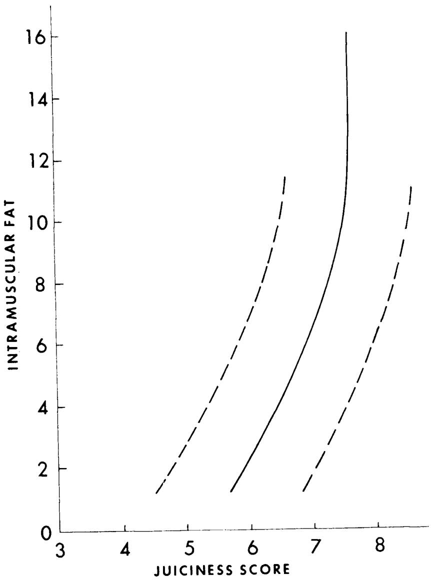

Figure 12.—The curvilinear relationship between juiciness score and intramuscular fat for unaged *Longissimus dorsi* from all grades (---- indicates P=0.05).

with the marbling rating for both unaged and aged ribeye. (The correlation coefficient was negative because high numerical values were assigned to high degrees of marbling but low numerical values were assigned to high scores for juiciness.) These results substantiate the belief that tender, juicy beef can be selected on the basis of the marbling characteristics.

Juiciness was apparently not correlated with lean color, and was significantly correlated with fiber autolysis only for unaged samples studied the second year. We have no logical explanation for the relatively high correlation between fiber autolysis and juiciness and tenderness for the unaged samples obtained the second year when other groups of unaged and aged samples fail to show any significant relationship between fiber autolysis and organoleptic properties. This emphasizes the need for studying samples from a large number of carcasses before attempting to draw conclusions that may be expected to apply generally.

Juiciness scores were not correlated with press fluid from either raw or cooked meat. This would substantiate the belief of other investigators (*32*, *34*) that juiciness scores of cooked meat do not reflect the amount of free fluid present in the meat but are perhaps more closely related to some constituent in meat that stimulates salivary secretion. This study and other reports (*3*, *22*, *39*) would suggest that the sensation of juiciness is given by the fat in the meat, particularly if the fat is well distributed in small deposits in the meat (well marbled).

Lean Flavor. The relationships between lean flavor and the creatine and creatinine content of raw and cooked meat are extremely interesting (table 56, appendix). Although only a few of the coefficients are statistically significant, the fact that most of the coefficients for creatine-lean flavor are negative while those for creatinine-lean flavor are positive would suggest that high creatine content is detrimental to desirable flavor but that high creatinine is desirable from a flavor standpoint. Since high creatinine is usually associated with low creatine, particularly in cooked meat, the results would indicate that only one of these compounds is associated with flavor. Both factors could be effective, but this appears unlikely because the correlation coefficient between creatine/creatinine ratio and lean flavor is no larger than the correlation coefficients for each of the compounds individually and lean flavor. More extensive investigations are needed before any positive conclusions can be drawn concerning the relationship between creatine and creatinine and flavor.

Although there appeared to be some relationship between lean flavor and soluble protein content for some groups of samples studied the third year, this correlation was not statistically significant when the data for all samples were considered. This variablilty indicates that additional study is needed before positive conclusions can be drawn on the possible relation of simple proteins to lean flavor.

Since Crocker (*8*) has indicated that cooked-meat flavor is "sulfury" and Bouthilet (*5*) suggested that meat flavor is due to some sulfur-containing compound, it might be expected that an estimation of sulfur compounds easily decomposed to yield hydrogen sulfide would give some index of flavor. Although some groups of samples studied during the last year of this investigation showed a very significant relationship between lean flavor and "volatile" sulfur, correlation studies on the combined data did not indicate that lean flavor was associated with the "volatile" sulfur in raw or cooked meat. This does not necessarily mean that some organic sulfur compounds, such as glutathione or methionine, do not contribute to meat flavor; it simply indicates that our method for obtaining an index of these compounds was not satisfactory or that the influence of other compounds on meat flavor simply is more pronounced. Additional studies on flavor will be required to answer these questions.

SUMMARY

This report summarizes the results of an investigation designed to provide fundamental information on beef needed to serve as a basis for devising more objective measures for grading carcass beef. During the investigation extensive chemical, biochemical, physical, histological, and organoleptic data were obtained on samples from 153 carcasses of beef animals of different grades (54 Prime grade, 72 Good grade, 27 Commercial cow) slaughtered from June 1949 to January 1952. It has not been within the scope of this study to attempt to apply the data to improvements or modifications in the grading of carcass beef.

Samples of *Longissimus dorsi* from the wholesale 6–12 rib cut were obtained from all carcasses, and samples of *Semitendinosus* from the wholesale cut of round were obtained on approximately one third of the carcasses. Samples were taken after 0, 2, and 4 weeks' aging at 34° F. (Some cuts from lightweight carcasses were not sampled after 4 weeks' aging because insufficient amounts of muscle tissue were available for an adequate sample.)

Certain very definite grade differences, as well as significant weight and muscle differences, were found. Changes occurring during aging and cooking were established. Various interrelationships between physical, chemical, histological, and organoleptic properties of meat were shown to be significant.

Grade Differences. From the results of the 3-year study certain very definite grade differences were established. It must be emphasized, however, that these are general mean differences and must not be interpreted to mean that all differences are apparent in all carcasses of the different grades.

Prime carcasses were fatter than Good carcasses. This would be expected since marbling is one of the characteristics used in grading and since it would be expected that variations in marbling would be associated with variations in separable fat. Also in conformity with grading practice was the fact that the amount of separable fat in Commercial cow carcasses was intermediate between that of Good grade animals and carcasses of Prime grade. Carcasses of animals slaughtered in

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January were fatter than those of animals slaughtered in August.

Good grade and Commercial cow carcasses contained a greater proportion of eye muscle in the rib cut than did Prime grade carcasses which was probably also a reflection of lower separable fat.

During aging at 34° F. the rib cut from light Good grade carcasses lost slightly more weight than did those from the other groups of carcasses.

Ribeye from Prime carcasses, as compared to that from carcasses of Good and Commercial grades, had a lower shear strength (both raw and cooked), more press fluid (raw), a greater specific conductance (raw), less nitrogen (cooked), more intramuscular and "linear" fat, more marbling, and brighter lean color. More drip loss but less evaporation loss was noted after broiling rib steaks from Prime as compared to Good grade carcasses. The *Longissimus dorsi* of broiled rib steaks from Prime grade carcasses had better lean flavor and were more tender than those from Good grade carcasses. Juiciness scores for ribeye from light Good grade carcasses were less than those for ribeye from the other groups of carcasses. For the first year's samples only, the collagen content of raw ribeye from Prime carcasses was less than that of raw ribeye from Good grade carcasses.

For almost all of these differences between grades, except those related to tenderness, ribeye from Commercial cow carcasses ranked between the means for the Good and Prime grade carcasses or well within the range of the Good grade animals. Although in some instances Commercial cow beef was as tender as Good, in most instances this was not the case.

Weight Differences. In addition to the grade differences there were some differences within grade due to carcass weight. Heavy carcasses were fatter than light carcasses. The ribeye from light carcasses contained less intramuscular and "linear" fat and was not as well marbled. Less fluid could be expressed from ribeye of light carcasses, and shear strength of cooked ribeye of light carcasses was greater. The muscle-fiber extensibility of raw ribeye from lightweight carcasses was less than that from heavy carcasses. Within the Good grade, juiciness of broiled ribeye was greater in the heavy carcasses.

These differences would be expected for the most part because carcass weight for these studies was largely indicative of animal age. Since older animals must be fatter to conform to a given grade classification, the weight-fat differences described above are completely logical. Also, the greater yield of press fluid from raw meat of heavy animals appears logical since the press fluid of raw meat from Prime grade carcasses was greater than that of Good.

Muscle Differences. Since two muscles were investigated during these studies, a summary of their differences should be of value from both the fundamental and practical standpoints. The raw *Longissimus dorsi* contained more intramuscular and "linear" fat, less creatine, less collagen, and less elastin than the *Semitendinosus*. Primary bundles in the ribeye were larger than those in the *Semitendinosus*, and the maximum elastin fiber diameter in the ribeye was much less than that in the *Semitendinosus*. The *Longissimus dorsi* exhibited a higher muscle fiber autolysis level than the *Semitendinosus*, and the autolysis increase with aging was more pronounced. Fat dispersion by broiling was greater for the *Longissimus dorsi*.

During broiling there was less drip loss but more evaporation loss for steaks from the round than for rib steaks. Broiled ribeye was more tender and juicy and had a better lean flavor than broiled *Semitendinosus.* However, the tenderness of *Semitendinosus* was improved more by aging than was that of the ribeye.

Not only were there differences between muscles, but the same muscle had somewhat different characteristics at different positions. The posterior portion of the ribeye contained less intramuscular and "linear" fat and was not as well marbled as the anterior portion. The center portion of the *Semitendinosus* contained more fat, exhibited a greater autolysis level, and had a lower raw shear strength than did either end. The muscle fiber diameter in the *Semitendinosus* decreased progressively from top to bottom.

Although the two muscles were quite different in their characteristics, differences between carcasses were reflected similarly in the two muscles. The fat content, specific conductance, and tenderness scores of the two muscles from different carcasses were very significantly correlated.

Changes During Aging. Aged raw ribeye, as compared to fresh, had a higher pH and specific conductance (Good grade only) and contained higher percentages of nonprotein nitrogen, free amino nitrogen, and creatinine but less soluble protein. Aging increased the autolysis level of ribeye but reduced the collagen content and muscle fiber extensibility. The color of the raw meat was improved by aging. Aging for 2 weeks improved the fat flavor, lean flavor, and tenderness of broiled ribeye. An additional 2-week aging period was usually detrimental to lean and fat flavor and had little additional tenderizing influence. There was a loss in aldolase, phosphorylase, and proteolytic activity during aging. Aged cooked ribeye, as compared to fresh cooked ribeye, contained more soluble protein, nonprotein nitrogen, amino nitrogen, and creatinine. Fat dispersion during cooking was reduced by aging the raw meat.

Changes During Cooking. Broiling meat to an internal temperature of 155° F. resulted in an increase in pH but reduced the specific conductance, penetrometer readings, and firmness readings (increased firmness). The shear strength of ribeye was increased by cooking but that of *Semitendinosus* was reduced. Fibers of cooked meat were more extensible than those of corresponding raw samples. Cooked meat, as compared to raw, contained more press fluid and creatinine but less soluble protein, collagen, and creatine.

These differences indicate that during cooking (broiling to 155° F.) the following changes occur in varying degrees:

(*a*) Muscle fibers are changed (denatured) so that their resistance to shear and their extensibility are increased.

(*b*) Collagen is hydrolyzed or denatured.

(*c*) Soluble proteins are denatured or condensed to more insoluble complexes.

(*d*) Creatine is changed to creatinine.

(*e*) Perimysial and endomysial fat is dispersed.

(*f*) The surface of the muscle fibers is sometimes slightly "eroded," which probably indicates that the fluid cytoplasmic material in the muscle fiber is coagulated only near the cell periphery.

Meat Properties Associated With Organoleptic Desirability. Shear strength of cooked meat was a good index of tenderness. Tenderness of unaged meat was also closely correlated with the intramuscular fat content and "marbling." Unaged raw meat with bright lean color was usually more tender than meat with a darker color. In these studies, collagen content of the meat was not significantly correlated with tenderness. Shear strength of raw meat; specific conductance of raw meat or cooked meat; penetrometer and firmness readings on raw or cooked meat; extent of fiber autolysis; and protein autolysis, as indicated by the nonprotein nitrogen content of raw or cooked meat, were not consistently or significantly related to tenderness of broiled steak.

Juiciness of broiled steak was closely associated with fat, as evaluated either by intramuscular fat or marbling rating. There was some indication from the results that this relationship between intramuscular fat and juiciness is not apparent above a certain intramuscular fat level (probably 7 to 8 percent). In other words, increased amounts of well-distributed fat up to 7 to 8 percent may improve juiciness, but increasing the fat content above this level will not generally increase juiciness scores. In these studies, juiciness was not consistently related to press fluid from raw or cooked meat or with any other chemical, physical, or histological property studied other than fat content and marbling.

Lean flavor was not significantly associated with any other property of meat evaluated in these studies. There was some suggestion that creatine and creatinine, soluble proteins, and simple sulfur compounds may be slightly associated with lean flavor, but the relationships were not consistent or significant.

LITERATURE CITED

(1) Andrews, Mona M., Guthneck, Barbara T., McBride, B. H. and Schweigert, B. S.
1952. Stability of Certain Respiratory and Glycolytic Enzyme Systems in Animal Tissues. Jour. Biol. Chem. 194: 715–719.

(2) Barbella, N. G., Tannor, B., and Johnson, T. G.
1939. Relation of Flavor and Juiciness of Beef to Fatness and Other Factors. 32d Annual Proceedings of the American Society of Animal Production, pp. 320–325.

(3) Beard, F. J.
1924. A Study of Tough and Tender Beef. Unpublished, M. S. Thesis, Iowa State College, Ames, Iowa.

(4) Black, W. H., Warner, K. F. and Wilson, C. V.
1931. Beef Production and Quality as Affected by Grade of Steer and Feeding Grain Supplement on Grass. U.S.D.A. Tech. Bull. 217.

(5) Bouthilet, R. J.
1951. Chicken Flavor: the Fractionation of the Volatile Components. Food Res. 16: 137–141.

(6) Branaman, G. A., Hankins, O. G. and Alexander, L. M.
1936. The Relation of Degree of Finish in Cattle to Production and Meat Factors. 29th Annual Proc. Am. Soc. An. Prod., 295.

(7) Bratzler, Lyman J.
1932. Measuring the Tenderness of Meat by Means of a Mechanical Shear. M. S. Thesis, Kansas State College, Manhattan, Kansas.

(8) Crocker, E. C.
1948. FLAVOR OF MEAT. Food Res. 13: 179–183.

(9) Deatherage, F. E. and Garnatz, George.
1952. A COMPARATIVE STUDY OF TENDERNESS DETERMINATION BY SENSORY PANEL AND BY SHEAR STRENGTH MEASUREMENTS. Food Technol. 6: 260–262.

(10) Diemair, W., Strohecker, R. and Keller, H.
1939. VOLATILE SULFUR COMPOUNDS (IN FOODSTUFFS). Z. anal. Chem. 116: 385–403.

(11) Duncan, D. B.
1952. ON THE PROPERTIES OF THE MULTIPLE COMPARISONS TEST. Virginia Journal of Science 3.

(12) Folin, Otto.
1914. ON THE DETERMINATION OF CREATINE AND CREATININE IN URINE. Jour. Biol. Chem. 17: 469–473.

(13) Gaddis, A. M., Hankins, O. G., and Hiner, R. L.
1950. RELATIONSHIPS BETWEEN THE AMOUNT AND COMPOSITION OF PRESS FLUID, PALATABILITY, AND OTHER FACTORS OF MEAT. Food Technol. 4: 498–503.

(14) Ginger, Irene D., Wachter, J. P., Doty, D. M., Schweigert, B. S., Beard, F. J., Pierce, J. C. and Hankins, O. G.
1954. EFFECT OF AGING AND COOKING ON THE DISTRIBUTION OF CERTAIN AMINO ACIDS AND NITROGEN IN BEEF MUSCLE. Food Res. 19: 410–416.

(15) Hall, J. L.
1932. MEASUREMENT OF ELECTRICAL RESISTANCE OF BEEF RIBEYE. Kansas Agr. Exp. Sta. Rept. to Meat Conference, p. 14.

(16) Hall, J. L.
1941. WATER IMHIBITION AND ISOELECTRIC POINT OF BRIGHT AND BLACK BEEF MUSCLE TISSUE. Kansas Agr. Exp. Sta. Rept. to Meat conference.

(17) Hall, J. L., Mackintosh, D. L. and Vail, Gladys
1944. QUALITY OF BEEF. Kansas Agr. Exp. Sta. Bull. 58.

(18) Hankins, O. G. and Howe, P. E.
1946. ESTIMATION OF THE COMPOSITION OF BEEF CARCASSES AND CUTS. U.S.D.A. Tech. Bull. No. 926.

(19) Harrison, D. L., Lowe, Belle, McClurg, B. R. and Shearer, P. S.
1949. PHYSICAL, ORGANOLEPTIC AND HISTOLOGICAL CHANGES IN THREE GRADES OF BEEF DURING AGING. Food Technol. 3: 284–288.

(20) Heim, Elmar.
1954. DIE METHODEN DER OBJEKTIVEN FLEISCHVERTEILUNG. Die Fleischwirtschaft 6: 74–77.

(21) Hiner, R. L., Hankins, O. G., Sloane, H. S., Fellers, C. R. and Anderson, E. E.
1953. FIBER DIAMETER IN RELATION TO TENDERNESS OF BEEF MUSCLE. Food Res. 18: 364–376.

(22) Husaini, S. A., Deatherage, F. E., Kunkle, L. E. and Draudt, H. N.
1950. STUDIES ON MEAT. I. THE BIOCHEMISTRY OF BEEF AS RELATED TO TENDERNESS. Food Technol. 4: 313–316.

(23) Husaini, S. A., Deatherage, F. E. and Kunkle, L. E.
1950. Studies on Meat. II. Observations on Relation of Biochemical Factors to Changes in Tenderness. Food Technol. 4: 366–369.

(24) Lowry, O. H., Gilligan, D. R. and Katersky, E. M.
1941. The Determination of Collagen and Elastin in Tissues With Results Obtained in Various Normal Tissues From Different Species. Jour. Biol. Chem. 139: 795–804.

(25) Mackintosh, D. L., Hall, J. L., and Vail, G. E.
1936. Some Observations Pertaining to Tenderness of Meat. Proc. Am. Soc. An. Prod., pp. 285–289.

(26) Marquette, Mona, and Schweigert, B. S.
1950. Stability of the Adenosinetriphosphatase System in Animal Tissues. Science 111: 660–661.

(27) Marquette, Mona, and Schweigert, B. S.
1950. Effect of Method of Homogenization of Beef Muscle Tissue on Activity of Succinic Dehydrogenase System. Proc. Soc. Exptl. Biol. Med. 74: 860–862.

(28) Mitchell, H. H., Zimmerman, R. L., and Hamilton, T. S.
1927. The Determination of the Amount of Connective Tissue in Meat. Jour. Biol. Chem. 71: 379.

(29) Munsell Color Plates, as prepared for and distributed by Natl. Live Stock and Meat Board, Chicago, Ill.

(30) Nelson, M. P., Lowe, B., and Helser, M. D.
1930. Influence of the Animal's Age Upon the Quality and Palatability of Beef. Iowa Agr. Exp. Sta. Bull. 272.

(31) 1945. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 6th ed., Association of Official Agricultural Chemists, Washington, D.C.

(32) Paul, Pauline
1943. Changes in the Palatability, Microscopic Appearance, and Electrical Resistance in Beef During the Onset and Passing of Rigor and During Subsequent Storage. Ph. D. Thesis, Iowa State College, Ames, Iowa.

(33) Ramsbottom, J. M., Strandine, E. J., and Koonz, C. H.
1945. The Comparative Tenderness of Representative Beef Muscles. Food Res. 10: 497–510.

(34) Satorium, Mary J., and Child, Alice M.
1938. Problems in Meat Research. Food Res. 3: 627–635.

(35) Sherman, Henry C.
1948. Food Products, pp. 137–171. The Macmillan Co.

(36) Snedecor, G. W.
1948. Statistical Methods. The Iowa State College Press, Ames, Iowa.

(37) Tannor, B., Clark, N. G., and Hankins, O. G.
1943. Mechanical Determination of the Juiciness of Meat. Jour. Agr. Res. 66: 403–412.

(38) Van Slyke, D. D.
1912. THE QUANTITATIVE DETERMINATION OF ALIPHATIC AMINO GROUPS. II. Jour. Biol. Chem. 12: 275–284.

(39) Wanderstock, J. J., and Miller, J. I.
1948. QUALITY AND PALATABILITY OF BEEF AS AFFECTED BY METHOD OF FEEDING AND CARCASS GRADE. Food Res. 13: 291–303.

(40) Wang, H.
1949. A HISTO-PHOTOELECTRIC METHOD OF COLLAGEN DETERMINATION IN MUSCLES. Anat. Rec. 105: 537.

(41) Wang, H., Rasch, Ellen, and Bates, Virginia.
1954. HISTOLOGICAL OBSERVATIONS ON FAT LOCI AND DISTRIBUTION IN COOKED BEEF. Food Res. 19: 314–322.

(42) Wang, H., Doty, D. M., Beard, F. J., Pierce, J. C., and Hankins, O. G.
1956. EXTENSIBILITY OF SINGLE BEEF MUSCLE FIBERS. Jour. Am. Sci. 15: 97–108.

(43) Wierbicki, E., Kunkle, L. E., Cahill, V. R., and Deatherage, F. E.
1956. POST MORTEM CHANGES IN MEAT AND THEIR POSSIBLE RELATION TO TENDERNESS TOGETHER WITH SOME COMPARISONS OF MEAT FROM HEIFERS, BULLS, STEERS, AND DIETHYLSTILBESTROL TREATED BULLS AND STEERS. Food Technol. 10: 80–86.

(44) Wierbicki, E., Cahill, V. R., and Deatherage, F. E.
1957. EFFECTS OF ADDED SODIUM CHLORIDE, POTASSIUM CHLORIDE, MAGNESIUM CHLORIDE, AND CITRIC ACID ON MEAT SHRINKAGE AT 70° C. AND OF ADDED SODIUM CHLORIDE ON DRIP LOSSES AFTER FREEZING AND THAWING. Food Technol. 11: 74–76.

APPENDIX

In all tables in the appendix the following designations are used to indicate the grade and weight classifications:

C_1-- Commercial cows
C_2-- Prime grade light cattle
C_3-- Prime grade heavy cattle
C_4-- Good grade light cattle
C_5-- Good grade heavy cattle

The analysis of variance tables are presented in the usual manner. For cases in which significant variation was found the multiple comparisons test described by Duncan (*11*) was used to separate the significant differences. The results of this test are denoted by ranking the effect means in order of magnitude and placing brackets around groups that contain no significant differences (5-percent level). The usual designations * and ** are used to indicate values significant at the 5-percent and 1-percent level, respectively.

In some cases angle transforms of the actual observed data were used for the variance analysis. For this, table 16.9 presented by Snedecor (*36*) was used.

TABLE 5.—*Calculated percentage carcass fat in different grades and weights of carcasses sampled in different months (average of 9 carcasses in each group)*

Class	C_2	C_3	C_4	C_5	C_1
June	34	38	24	28	------
August	34	37	24	26	32
October	------	------	25	27	32
January	39	40	26	27	36

TABLE 5a.—*Analysis of variance for Orthogonic August and January data* [1]

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	588.5595	147.1399	**37.58
Years	2	6.5179	3.2589	---------
Month	1	39.4471	39.4471	**10.08
Classes × month	4	36.5488	9.1372	2.33
Error	18	70.4741	3.9152	---------
Total	29	741.5474	----------	---------

Significant effects:

Month means—

Aug.	Jan.
31.45	34.10

Class means—

C_4	C_5	C_1	C_2	C_3
25.89	27.70	35.53	36.85	38.40

[1] Angle transforms of percentages used.

Table 6.—*Median percentages of* Longissimus dorsi *muscle in various parts of wholesale rib cut from carcasses of different grades and weights*

Class	C_2	C_3	C_4	C_5	C_1
11–12 rib	24	22	30	27	26
9–10 rib	16	15	21	20	18
7– 8 rib	11	9	11	11	10

Table 7.—*Average lean color ratings of* Longissimus dorsi *muscle from different grades and weights of carcasses at different aging periods*

Aging (weeks)	Year	Class				
		C_2	C_3	C_4	C_5	C_1
0	1	5	4	5	6	4
	2	4	3	5	5	5
	3	4	3	5	5	5
2	1	3	3	4	5	4
	2	2	2	4	4	3
	3	3	2	3	3	3
4	1	3	3	3	4	4
	2	----	2	----	3	3
	3	----	3	----	3	3

Table 8.—*Analysis of variance and significant mean differences in lean color of* Longissimus dorsi *from carcasses of different grades and weights sampled in August and January*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	49. 53	12. 38	**4. 17
Years	2	18. 72	9. 36	3. 15
Month	1	3. 67	3. 67	1. 24
Aging	1	52. 01	52. 01	**17. 51
Classes × month	4	5. 37	1. 34	--------
Classes × aging	4	5. 87	1. 46	--------
Month × aging	1	1. 01	1. 01	--------
Classes × month × aging	4	11. 36	2. 84	--------
Error	38	112. 95	2. 97	--------
Total	59	260. 49	--------	--------

Significant mean differences:

Aging:

0	2 weeks
4. 15	2. 83

Classes:

C_3	C_2	C_4	C_1	C_5
2. 54	3. 17	3. 33	4. 17	4. 25

Table 9.—*Average subjective marbling ratings for* Longissimus dorsi *from different grades and weights of carcasses*

Rib section	Year	Class				
		C_2	C_3	C_4	C_5	C_1
11th	2	1. 6	1. 9	3. 7	3. 4	2. 6
	3	3. 0	2. 1	3. 8	3. 2	2. 3
9th	2	1. 9	1. 8	3. 5	3. 2	3. 1
	3	2. 3	1. 6	3. 3	2. 7	2. 3
7th	2	----	1. 6	----	2. 8	2. 5
	3	----	1. 8	----	2. 4	2. 0

Table 10.—*Analysis of variance for Orthogonic August and January data*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	33. 08	8. 27	**8. 44
Years	1	9. 12	9. 12	**9. 31
Month	1	. 02	. 02	---------
Rib section	1	2. 12	2. 12	2. 16
Classes × month	4	. 67	. 16	---------
Classes × rib section	4	. 57	. 14	---------
Month × rib section	1	. 60	. 60	---------
Classes × month × rib section	4	. 58	. 14	---------
Error	19	18. 63	. 98	---------
Total	39	65. 39	--------	---------

Significant mean differences:

Year means—

3d	2d
2. 20	2. 88

Class means—

C_3	C_2	C_1	C_5	C_4
1. 94	2. 00	2. 31	2. 75	3. 69

TABLE 11.—*Average shear values for* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are average value from 9 carcasses; other figures are averages of 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
June	0	5. 1	7. 0	6. 5	8. 2	----
	2	6. 0	6. 9	5. 5	7. 8	----
	4	5. 7	6. 7	8. 1	8. 2	----
August	0	6. 2	7. 5	6. 8	7. 2	7. 6
	2	6. 6	6. 4	6. 6	8. 4	7. 0
	4	4. 2	6. 9	7. 0	8. 0	6. 9
October	0	----	----	8. 2	9. 2	7. 7
	2	----	----	8. 9	9. 4	6. 6
	4	----	----	6. 9	7. 3	6. 4
January	0	6. 8	5. 9	7. 9	6. 9	7. 0
	2	6. 7	6. 0	7. 1	6. 6	5. 6
	4	5. 2	5. 8	8. 3	7. 1	5. 6
COOKED						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
June	0	9. 2	9. 8	13. 9	15. 4	----
	2	7. 9	8. 7	9. 9	10. 2	----
	4	9. 0	8. 2	8. 5	8. 6	----
August	0	11. 3	10. 0	13. 9	11. 4	12. 4
	2	8. 5	8. 1	9. 5	8. 7	10. 0
	4	8. 5	7. 8	----	8. 6	7. 9
October	0	----	----	12. 4	11. 2	11. 6
	2	----	----	9. 4	9. 9	10. 2
	4	----	----	9. 6	8. 6	8. 6
January	0	10. 0	8. 1	13. 5	11. 9	12. 8
	2	8. 0	6. 8	9. 7	10. 0	9. 9
	4	7. 5	7. 1	8. 0	9. 2	10. 0

TABLE 12.—*Average shear values for* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Average values of 3–9 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	16. 3	15. 9	16. 6	18. 3	15. 8
2	15. 1	15. 4	18. 2	18. 5	14. 2
4	17. 3	18. 3	19. 3	19. 1	14. 9
COOKED					
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	10. 4	12. 2	13. 2	12. 6	14. 2
2	9. 6	9. 5	9. 5	9. 9	10. 8
4	------	10. 7	------	10. 6	------

TABLE 13.—*Analysis of variance and significant mean differences in shear strength of cooked* Longissimus dorsi *from carcasses of different grades and weights (sampled in August and January) after different aging periods*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	200. 33	50. 08	**8. 36
Years	2	98. 70	49. 35	**8. 24
Month	1	4. 92	4. 92	---------
Aging	1	199. 44	199. 44	**33. 30
Classes × month	4	23. 67	5. 91	---------
Classes × aging	4	15. 53	3. 88	---------
Month × aging	1	. 69	. 69	---------
Classes × month × aging	4	3. 90	. 97	---------
Error	38	227. 55	5. 99	---------
Total	59	774. 73	--------	---------

Significant mean differences:

Aging:

0	2 weeks
11. 30	8. 72

Years:

3d	1st	2d
8. 74	10. 48	10. 80

Classes:

C_3	C_2	C_5	C_1	C_4
8. 05	9. 17	10. 08	11. 12	11. 62

Table 14.—*Average specific conductance for* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are average values from 9 carcasses; other figures are averages of 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
		RAW				
		10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos
June	0	306	262	228	215	-----
	2	279	266	310	286	-----
	4	358	238	287	285	-----
August	0	258	289	187	284	285
	2	281	270	311	287	278
	4	152	223	301	284	232
October	0	-----	-----	228	224	230
	2	-----	-----	275	267	292
	4	-----	-----	265	283	247
January	0	297	265	190	240	247
	2	275	275	289	286	268
	4	319	240	349	297	243
		COOKED				
		10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos
June	0	258	203	254	243	-----
	2	196	208	234	232	-----
	4	179	183	211	217	-----
August	0	244	244	256	252	256
	2	229	211	242	242	225
	4	173	188	-----	212	184
October	0	-----	-----	244	241	252
	2	-----	-----	229	229	221
	4	-----	-----	250	207	194
January	0	227	230	230	254	234
		197	202	246	226	228
	4	214	163	267	209	200

TABLE 15.—*Analysis of variance and significant mean differences in specific conductance of raw* Longissimus dorsi *from carcasses of different grades and weights (sampled in August and January) after different aging periods*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	27, 695. 1	6, 923. 8	1. 80
Years	2	53, 532. 4	26, 766. 2	**6. 96
Month	1	4, 477. 4	4, 477. 4	1. 16
Aging	1	28, 366. 9	28, 366. 9	**7. 37
Classes × month	4	14, 482. 6	3, 620. 6	----------
Classes × aging	4	49, 372. 9	12, 343. 2	*3. 21
Month × aging	1	170. 4	170. 4	----------
Classes × month × aging	4	9, 731. 2	2, 432. 8	----------
Error	38	146, 217. 0	3, 847. 8	----------
Total	59	334, 045. 8	----------	----------

Significant mean differences:

Classes × aging interaction:

Aging	C_1	C_2	C_3	C_4	C_5
0	265	265	276	179	258
14	277	271	280	290	278

Aging:

0	2 weeks
248	279

Years:

3d	1st	2d
240	261	291

Table 16.—*Analysis of variance and significant mean differences in specific conductance of cooked* Longissimus dorsi *from carcasses of different grades and weights (sampled in August and January) after different aging periods*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	13, 713. 2	3, 428. 3	1. 82
Years	2	61, 792. 3	30, 896. 1	**16. 40
Month	1	10, 659. 7	10, 659. 7	*5. 66
Aging	1	9, 919. 0	9, 919. 0	*5. 27
Classes × month	4	2, 628. 6	657. 2	---------
Classes × aging	4	7, 370. 3	1, 842. 6	---------
Month × aging	1	69. 0	69. 0	---------
Classes × month × aging	4	4, 351. 6	1, 087. 9	---------
Error	38	71, 575. 4	1, 883. 6	---------
Total	59	182, 079. 1	--------	---------

Significant mean differences:

Aging:

0	2 weeks
242	224

Month:

Jan.	Aug.
224	243

Year:

3d	2d	1st
203	241	257

Table 17.—*Average specific conductance for* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Average values from 3–9 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos
0	263	242	208	238	282
2	318	285	313	290	311
4	296	271	330	307	308
COOKED					
	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos	10^{-5}mhos
0	278	187	218	200	222
2	253	238	214	206	212
4	-------	224	-------	224	-------

TABLE 18.—*Average penetrometer readings for* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are average values from 6 carcasses; other figures are averages of 3–6 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		mm.	*mm.*	*mm.*	*mm.*	*mm.*
June	0	189	158	143	165	-----
	2	183	167	186	159	-----
	4	------	161	------	160	-----
August	0	181	156	175	168	171
	2	178	190	208	161	197
	4	------	140	------	149	-----
October	0	------	------	158	163	161
	2	------	------	226	181	153
	4	------	------	------	167	145
January	0	169	150	162	175	162
	2	179	130	174	194	180
	4	------	130	------	143	166
COOKED						
		mm.	*mm.*	*mm.*	*mm.*	*mm.*
June	0	85	79	107	92	------
	2	93	89	93	84	------
	4	------	91	------	93	------
August	0	91	92	130	93	105
	2	92	91	109	80	104
	4	------	78	------	81	83
October	0	------	------	93	86	84
	2	------	------	95	99	83
	4	------	------	------	80	78
January	0	72	70	91	100	79
	2	86	87	86	84	86
	4	------	70	------	92	72

TABLE 19.—*Average penetrometer readings for* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Average values of 3–5 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
0	139	136	117	139	105
2	149	154	166	153	134
4	------	159	------	149	131
COOKED					
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
0	77	72	66	63	72
2	100	79	89	66	80
4	------	86	------	88	------

TABLE 20.—*Press fluid from* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are average values from 6 carcasses; other figures are averages of 3–6 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	25	24	24	24	----
	2	17	16	15	16	----
	4	7	15	12	13	----
August	0	25	32	23	27	24
	2	18	28	15	17	18
	4	13	25	14	16	11
October	0	----	----	22	26	26
	2	----	----	15	20	21
	4	----	----	11	17	16
January	0	26	28	22	25	25
	2	22	21	15	14	22
	4	14	20	12	9	19
COOKED						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	38	36	31	35	----
	2	40	32	33	34	----
	4	----	37	31	37	----
August	0	38	34	36	36	36
	2	40	39	37	35	37
	4	39	44	----	37	----
October	0	----	----	38	37	42
	2	----	----	37	37	40
	4	----	----	37	35	30
January	0	38	39	39	41	40
	2	36	37	38	37	38
	4	36	35	----	33	35

TABLE 21.—*Press fluid from* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures for raw are averages of 3—6 carcasses; figures for cooked are averages from 2 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
0	22	27	21	23	27
2	16	20	16	17	18
4	10	18	15	10	14
COOKED					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
0	35	35	33	34	31
2	34	37	35	37	34
4	--------	37	--------	35	-------

TABLE 22.—*Total nitrogen content of cooked* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Each figure is an average value of 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	4. 56	4. 52	4. 73	4. 72	----
	2	4. 28	4. 23	4. 60	4. 44	----
	4	----	4. 41	----	4. 55	----
August	0	4. 51	4. 36	4. 71	4. 52	4. 53
	2	4. 30	4. 34	4. 52	4. 56	4. 54
	4	4. 32	4. 31	----	4. 42	4. 48
October	0	----	----	4. 78	4. 67	4. 37
	2	----	----	4. 60	4. 54	4. 38
	4	----	----	4. 51	4. 62	4. 38
January	0	4. 53	4. 34	4. 69	4. 55	4. 51
	2	4. 64	4. 27	4. 57	5. 24	4. 53
	4	4. 69	4. 33	4. 67	4. 77	4. 75
SEMITENDINOSUS						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
	0	4. 49	4. 66	5. 01	5. 02	4. 80
	2	4. 52	4. 61	4. 62	4. 69	4. 67
	4	----	4. 50	----	4. 73	----

Table 23.—*Analysis of variance and significant mean differences in nitrogen content of cooked* Longissimus dorsi *from carcasses of different grades and weights (sampled in August and January) after different aging periods*

Source	*d.f*	*Sum of squares*	*Mean square*	*F*
Classes	4	1. 8345	0. 4586	*2. 97
Years	2	. 9020	. 4510	2. 92
Month	1	. 2262	. 2262	1. 46
Aging	1	. 0004	. 0004	---------
Classes × month	4	. 9603	. 2401	1. 56
Classes × aging	4	. 6316	. 1579	1. 02
Month × aging	1	. 0891	. 0891	---------
Classes × month × aging	4	. 1344	. 0336	---------
Error	38	5. 7110	. 1544	---------
Total	59	10. 4895	--------	---------

Significant mean differences:

Classes:

C_3	C_2	C_1	C_5	C_4
4. 40	4. 45	4. 46	4. 61	4. 62

Table 24.—*Intramuscular fat content of different sections of raw* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights*

[Each figure is an average value of 3–9 carcasses]

Month slaughtered	Muscle section	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	11–12 rib	8. 0	9. 9	3. 1	6. 0	---
	9–10 rib	9. 1	10. 5	3. 7	6. 5	---
	7–8 rib	6. 5	10. 5	4. 0	8. 1	---
August	11–12 rib	6. 4	7. 7	2. 7	4. 5	5. 6
	9–10 rib	6. 9	8. 0	3. 0	4. 9	5. 6
	7–8 rib	7. 1	9. 4	4. 0	5. 8	6. 8
October	11–12 rib	---	----	2. 6	3. 0	5. 5
	9–10 rib	---	----	3. 5	3. 8	6. 6
	7–8 rib	---	----	2. 7	4. 2	7. 3
January	11–12 rib	7. 7	10. 9	3. 4	4. 2	5. 8
	9–10 rib	8. 0	11. 8	3. 7	5. 0	6. 8
	7–8 rib	7. 5	13. 1	4. 6	5. 4	8. 8
SEMITENDINOSUS						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
	Top	4. 5	4. 9	2. 0	2. 3	3. 3
	Middle	4. 2	6. 1	2. 3	2. 7	2. 8
	Bottom	3. 2	5. 0	4. 1	2. 2	2. 1

TABLE 25.—*Analysis of variance and significant mean differences in intramuscular fat content of raw* Longissimus dorsi *from carcasses of different grades and weights (sampled in August and January)*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	537. 8020	134. 4505	**16. 91
Years	1	25. 6851	25. 6851	3. 23
Month	1	21. 3935	21. 3935	2. 69
Position	1	6. 4923	6. 4923	---------
Classes × month	4	60. 0843	15. 0211	1. 89
Classes × position	4	2. 2202	. 5551	---------
Month × position	1	. 3315	. 3315	---------
Classes × month × position	4	3. 7505	. 9376	---------
Error	19	143. 1576	7. 9532	---------
Total	39	800. 9167	----------	---------

Significant mean differences

Classes:

C_4	C_5	C_1	C_2	C_3
3. 10	4. 64	6. 30	8. 10	8. 65

TABLE 26.—*The nonprotein nitrogen content of raw and cooked* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are averages from 6 carcasses; other figures are averages of 3–6 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	0. 33	0. 33	0. 32	0. 32	-----
	2	. 34	. 34	. 35	. 36	-----
	4	. 40	. 34	. 34	. 36	-----
August	0	. 32	. 33	. 35	. 33	0. 34
	2	. 34	. 33	. 37	. 34	. 34
	4	. 37	. 33	. 40	. 35	. 36
October	0	------	------	. 33	. 34	. 32
	2	------	------	. 36	. 36	. 34
	4	------	------	. 38	. 37	. 35
January	0	. 34	. 33	. 34	. 36	. 33
	2	. 36	. 34	. 36	. 37	. 34
	4	. 37	. 34	. 38	. 38	. 35
COOKED						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	0. 35	0. 34	0. 38	0. 34	-----
	2	. 37	. 37	. 39	. 38	-----
	4	. 42	. 36	. 36	. 40	-----
August	0	. 34	. 36	. 35	. 34	0. 35
	2	. 38	. 35	. 40	. 34	. 37
	4	. 35	. 35	------	. 36	-----
October	0	------	------	. 36	. 36	. 34
	2	------	------	. 40	. 38	. 35
	4	------	------	. 42	. 40	. 38
January	0	. 34	. 34	. 36	. 39	. 34
	2	. 38	. 35	. 37	. 42	. 37
	4	. 40	. 43	. 39	. 47	. 38

TABLE 27.—*The nonprotein nitrogen content of raw and cooked* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of 2–6 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
0	0. 34	0. 33	0. 33	0. 34	0. 34
2	. 35	. 35	. 36	. 36	. 35
4	. 35	. 35	. 35	. 36	. 35
COOKED					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
0	0. 32	0. 31	0. 38	0. 34	0. 33
2	. 37	. 35	. 40	. 38	. 32
4	------	. 38	------	. 41	------

TABLE 28.—*The soluble protein content of raw and cooked* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures for *Longissimus dorsi* are averages of 3–9 carcasses; those for *Semitendinosus* are averages of 2–3 carcasses]

	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Raw	0	5. 1	4. 6	5. 1	5. 2	5. 1
	2	4. 5	3. 8	4. 7	4. 3	4. 6
	4	----	2. 8	----	4. 3	4. 4
Cooked	0	. 52	. 97	. 57	. 71	. 53
	2	. 82	. 88	. 99	1. 06	1. 29
	4	----	1. 16	----	1. 20	1. 00
SEMITENDINOSUS						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Raw	0	4. 7	4. 5	4. 6	5. 0	5. 0
	2	3. 3	3. 5	3. 6	4. 0	4. 0
	4	----	3. 7	----	3. 7	4. 2
Cooked	0	. 44	. 32	. 39	. 34	. 32
	2	. 47	. 41	. 70	. 49	. 74
	4	----	. 96	----	. 74	----

TABLE 29.—*The creatine content of raw and cooked* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are averages from 6 carcasses; other figures are averages of 3–6 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
June	0	298	323	312	299	----
	2	269	311	330	308	----
	4	249	303	274	280	----
August	0	303	358	306	327	314
	2	340	313	329	301	341
	4	360	317	419	319	343
October	0	----	----	329	325	313
	2	----	----	332	326	294
	4	----	----	400	309	304
January	0	294	264	288	279	283
	2	300	267	306	305	338
	4	313	251	315	296	304
COOKED						
		mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
June	0	307	303	335	304	----
	2	240	306	289	309	----
	4	262	291	269	305	----
August	0	332	333	294	311	326
	2	337	294	350	301	350
	4	323	295	----	317	----
October	0	----	----	302	353	312
	2	----	----	351	340	288
	4	----	----	412	303	311
January	0	284	287	294	308	304
	2	292	255	302	313	290
	4	301	223	308	293	322

TABLE 30.—*The creatine content of raw and cooked* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of 2–6 carcasses]

Aging Period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
0	331	359	327	340	370
2	313	301	357	363	382
4	306	323	367	317	362
COOKED					
	mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
0	268	255	247	279	304
2	290	256	326	315	331
4	------	274	------	315	------

TABLE 31.—*The creatinine content of raw and cooked* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Zero aging figures are averages from 6 carcasses; other figures are averages of 3–6 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RAW						
		mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
June	0	12	13	24	14	----
	2	15	20	22	29	----
	4	21	23	33	26	----
August	0	16	13	18	15	18
	2	14	20	21	18	19
	4	16	19	24	17	18
October	0	----	----	11	13	14
	2	----	----	13	16	16
	4	----	----	15	18	15
January	0	11	12	10	9	11
	2	13	14	10	9	11
	4	15	15	15	16	15
COOKED						
		mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
June	0	31	44	42	36	----
	2	30	39	39	46	----
	4	34	37	45	40	----
August	0	30	29	29	29	30
	2	32	34	35	35	33
	4	31	33	----	30	----
October	0	----	----	30	27	34
	2	----	----	29	31	32
	4	----	----	31	34	30
January	0	23	26	24	25	27
	2	32	29	20	30	27
	4	31	30	32	28	31

TABLE 32.—*The creatinine content of raw and cooked* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of 2–6 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
0	14	15	20	16	19
2	15	20	20	28	21
4	19	22	19	23	20
COOKED					
	mg./100 g.	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*	*mg./100 g.*
0	23	22	30	32	35
2	31	32	31	33	35
4	------	32	------	32	------

TABLE 33.—*The "volatile" sulfur content of raw and cooked* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of 2–10 carcasses]

	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
		μg./g.	*μg./g.*	*μg./g.*	*μg./g.*	*μg./g.*
Raw	0	14. 1	12. 9	13. 9	12. 1	15. 2
	2	13. 9	13. 7	14. 8	15. 4	14. 1
	4	----	12. 6	----	16. 1	14. 4
Cooked	0	14. 3	14. 6	15. 1	14. 5	15. 5
	2	13. 7	16. 4	14. 6	17. 6	15. 2
	4	----	19. 9	----	15. 4	14. 4
SEMITENDINOSUS						
		μg./g.	*μg./g.*	*μg./g.*	*μg./g.*	*μg./g.*
Raw	0	12. 9	14. 5	13. 3	12. 0	13. 8
	2	14. 6	11. 9	13. 3	14. 5	13. 8
	4	12. 0	----	13. 2	14. 3	13. 8
Cooked	0	14. 7	16. 3	14. 8	14. 9	14. 1
	2	14. 1	15. 0	14. 2	14. 7	14. 6
	4	----	14. 2	----	13. 9	14. 1

TABLE 34.—*The muscle fiber diameter in raw* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 2–9 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI					
	microns	*microns*	*microns*	*microns*	*microns*
0	46	48	45	48	56
2	47	50	40	41	------
4	43	41	------	39	------
SEMITENDINOSUS					
	microns	*microns*	*microns*	*microns*	*microns*
0	52	50	49	57	63
2	55	49	46	51	56
4	46	37	41	45	46

TABLE 35.—*Range of muscle bundle area in raw* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights*

	Class				
	C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI					
	mm^2	*mm^2*	*mm^2*	*mm^2*	*mm^2*
Primary	0. 19– 0. 66	0. 31–0. 43	0. 10–0. 64	0. 11–0. 33	0. 14– 0. 39
Secondary	1. 6 –10. 1	2. 5 –2. 8	1. 9 –7. 6	1. 6 –5. 4	1. 8 – 7. 9
SEMITENDINOSUS					
	mm^2	*mm^2*	*mm^2*	*mm^2*	*mm^2*
Primary	0. 07– 0. 30	0. 08	0. 07–0. 20	0. 08– 0. 47	0. 06– 0. 25
Secondary	. 26– 7. 2	. 54	. 44–5. 6	. 53–10. 7	. 65–14. 0

TABLE 36.—*The elastin content (by volume) of raw unaged* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights*

[Figures are averages of values from 3–6 carcasses]

Month slaughtered	Class				
	C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0. 8	0. 7	0. 8	0. 9	------
August	. 7	. 8	. 8	. 7	0. 9
October	------	------	. 6	. 5	. 7
January	. 6	------	. 6	. 8	. 7
SEMITENDINOSUS					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
	2. 8	2. 0	1. 7	1. 6	1. 9

TABLE 37.—*The collagen content (percent by volume) of raw and cooked* Longissimus dorsi *from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month Slaughtered	Aging Period (weeks)	Class C_2	Class C_3	Class C_4	Class C_5	Class C_1
RAW						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	1. 5	1. 3	1. 5	1. 5	----
	2	. 8	1. 1	1. 1	1. 3	----
	4	. 8	. 7	1. 6	. 9	----
August	0	1. 1	1. 4	. 9	1. 5	1. 2
	2	. 8	. 7	. 9	1. 1	1. 1
	4	. 3	. 7	. 8	. 8	. 8
October	0	----	----	1. 6	1. 4	1. 3
	2	----	----	1. 2	1. 0	. 8
	4	----	----	. 5	. 9	. 7
January	0	. 8	1. 1	1. 0	1. 1	1. 0
	2	. 9	. 9	. 8	1. 1	. 8
	4	. 3	. 7	. 6	. 8	. 8
COOKED						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	0. 7	0. 9	0. 8	1. 0	----
	2	. 8	. 7	. 7	1. 0	----
	4	----	. 9	. 8	. 9	----
August	0	. 8	. 7	. 8	1. 0	. 8
	2	. 7	. 7	. 7	. 8	. 7
	4	. 3	. 6	----	. 7	. 8
October	0	----	----	1. 1	. 9	1. 0
	2	----	----	. 9	. 8	. 7
	4	----	----	----	. 6	. 6
January	0	. 7	. 9	. 8	. 7	. 7
	2	. 7	. 8	. 8	. 7	. 6
	4	----	. 5	----	. 7	. 7

TABLE 38.—*The collagen content (percent by volume) of raw and cooked* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Aging period (weeks)	Class				
	C_2	C_3	C_4	C_5	C_1
RAW					
	percent	*percent*	*percent*	*percent*	*percent*
0	3. 1	3. 0	2. 8	2. 6	2. 6
2	2. 1	2. 2	1. 9	1. 9	2. 0
4	1. 9	1. 8	1. 5	1. 8	2. 1
COOKED					
	percent	*percent*	*percent*	*percent*	*percent*
0	2. 1	1. 8	1. 7	1. 9	1. 8
2	1. 4	1. 5	1. 2	1. 5	1. 8
4	------	1. 5	------	1. 2	------

TABLE 39.—*The "linear" fat level in raw* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Muscle section	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
		mm/150 mm²	*mm/150 mm²*	*mm/150 mm²*	*mm/150 mm²*	*mm/150 mm²*
June	11–12 rib	29	45	23	27	----
	9–10 rib	37	35	32	33	----
	7–8 rib	----	42	----	27	----
August	11–12 rib	35	33	14	30	28
	9–10 rib	38	48	20	34	35
	7–8 rib	----	54	----	46	44
October	11–12 rib	----	----	19	14	29
	9–10 rib	----	----	25	24	42
	7–8 rib	----	----	----	31	53
January	11–12 rib	27	37	19	21	26
	9–10 rib	41	47	25	30	38
	7–8 rib	----	41	----	35	46
SEMITENDINOSUS						
		mm/150 mm²	*mm/150 mm²*	*mm/150 mm²*	*mm/150 mm²*	*mm/150 mm²*
	Top	11	21	15	14	20
	Middle	21	37	15	23	29
	Bottom	----	27	----	20	29

TABLE 40.—*Muscle fiber autolysis rating for raw* Longissimus dorsi *and* Semitendinosus *from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
June	0	1. 8	1. 2	0. 6	0. 7	----
	2	2. 9	1. 7	1. 8	1. 9	----
	4	2. 0	2. 6	2. 5	3. 0	----
August	0	1. 0	. 9	. 1	. 9	1. 1
	2	2. 6	1. 0	1. 8	2. 4	1. 7
	4	3. 0	1. 1	3. 0	2. 6	3. 0
October	0	----	----	1. 7	2. 0	1. 1
	2	----	----	2. 6	2. 5	2. 1
	4	----	----	2. 3	2. 3	2. 6
January	0	1. 3	. 7	. 8	. 8	. 4
	2	2. 3	1. 4	2. 1	2. 7	2. 0
	4	1. 7	2. 1	2. 7	2. 9	2. 3
SEMITENDINOSUS						
	0	0. 5	0. 5	0. 4	0. 6	0. 6
	2	. 5	1. 1	. 9	1. 2	. 8
	4	. 6	. 5	1. 2	. 6	. 5

TABLE 41.—*Drip loss during broiling of rib and round steaks from carcasses of different grades and weights after different aging periods*

[Figures are average of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
RIB STEAKS						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	14. 8	15. 0	9. 0	10. 5	----
	2	11. 7	12. 5	7. 5	9. 0	----
	4	7. 7	10. 0	5. 3	7. 0	----
August	0	12. 8	14. 0	10. 1	10. 2	14. 1
	2	10. 7	13. 1	8. 5	7. 7	10. 0
	4	6. 0	11. 4	----	7. 4	9. 4
October	0	----	----	10. 7	12. 8	14. 6
	2	----	----	8. 2	10. 5	11. 9
	4	----	----	----	8. 6	9. 2
January	0	14. 4	15. 5	10. 6	12. 4	16. 4
	2	14. 3	14. 8	9. 5	10. 1	14. 3
	4	9. 1	12. 0	7. 3	7. 6	13. 7
ROUND STEAKS						
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
	0	8. 3	8. 7	9. 3	9. 0	8. 8
	2	10. 4	12. 8	10. 1	12. 3	13. 0
	4	----	13. 6	----	9. 3	10. 5

TABLE 42.—*Analysis of variance for combined 3 years' orthogonic data (August and January samples) for drip loss of rib steaks from carcasses of different grades and weights*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	329. 6276	82. 4069	**15. 69
Years	2	163. 9435	81. 4718	**15. 52
Month	1	60. 4210	60. 4210	**11. 51
Aging	1	63. 0895	63. 0895	**12. 01
Classes × month	4	22. 7967	5. 6992	1. 09
Classes × aging	4	19. 7691	4. 9423	----------
Month × aging	1	13. 3934	13. 3934	2. 55
Classes × month × aging	4	4. 0815	1. 0204	----------
Error	38	199. 5374	5. 2510	----------
Total	59	876. 6597	----------	----------

The significant mean differences were:

(*a*) Aging:

0	2 weeks
12.99	11. 31

(*b*) Month slaughtered:

Aug.	Jan.
11.35	12.96

(*c*) Year sampled:

1st	2d	3d
10.55	12.15	13.80

(*d*) Carcass grade and weight:

C_4	C_5	C_2	C_1	C_3
9.62	10.33	13.20	13.55	14.31

TABLE 43.—*Evaporation loss during broiling of rib and round steaks from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
		Rib steaks				
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
June	0	11. 9	12. 8	13. 3	11. 0	----
	2	13. 7	12. 5	13. 6	11. 1	----
	4	11. 1	11. 3	12. 9	9. 0	----
August	0	12. 1	11. 2	14. 1	11. 5	11. 5
	2	13. 0	13. 4	14. 3	13. 3	13. 0
	4	11. 6	12. 4	----	13. 8	14. 6
October	0	----	----	13. 6	12. 2	12. 3
	2	----	----	13. 5	13. 7	14. 1
	4	----	----	----	14. 8	14. 8
January	0	12. 9	10. 7	13. 9	12. 4	11. 8
	2	13. 2	12. 5	14. 5	15. 9	14. 2
	4	----	11. 9	14. 0	14. 0	14. 1
		Round steaks				
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
	0	15. 3	15. 2	19. 7	17. 0	21. 5
	2	17. 6	15. 6	16. 9	19. 9	19. 5
	4	----	14. 7	----	17. 5	19. 0

TABLE 44.—*Analysis of variance for combined 3 years' orthogonic data (August and January samples) for evaporation loss of rib steaks from carcasses of different grades and weights*

Source	d.f.	Sum of squares	Mean square	F
Classes	4	70. 8561	17. 7140	**6. 42
Years	2	27. 9408	13. 9704	*5. 07
Month	1	3. 3333	3. 3333	1. 21
Aging	1	69. 0993	69. 0993	**25. 05
Classes × month	4	19. 1333	4. 7833	1. 73
Classes × aging	4	15. 9822	3. 9968	1. 45
Month × aging	1	2. 5463	2. 5463	---------
Classes × month × aging	4	2. 7827	. 6956	---------
Error	38	104. 8043	2. 7580	---------
Total	59	316. 4833	----------	---------

The significant mean differences were:

(a) Aging:

0	2 weeks
11. 89	13. 65

(b) Years:

2d	1st	3d
12. 30	12. 40	13. 55

(c) Carcass grade and weight:

C_3	C_1	C_2	C_5	C_4
11. 90	12. 11	12. 50	12. 81	14. 46

TABLE 45.—*Lean flavor scores for* Longissimus dorsi *and* Semitendinosus *from broiled steaks from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
June	0	7. 1	7. 4	6. 2	6. 7	----
	2	8. 0	7. 5	7. 3	7. 5	----
	4	8. 0	7. 8	7. 0	7. 3	----
August	0	7. 4	7. 4	6. 1	6. 5	6. 0
	2	7. 8	7. 9	7. 7	7. 7	7. 0
	4	8. 3	7. 6	7. 0	7. 1	7. 0
October	0	----	----	6. 4	6. 6	6. 6
	2	----	----	7. 2	7. 2	7. 5
	4	----	----	6. 9	6. 9	6. 9
January	0	7. 4	7. 3	6. 5	6. 9	7. 2
	2	7. 9	7. 5	7. 0	7. 1	7. 3
	4	8. 0	7. 6	6. 8	7. 2	7. 1
SEMITENDINOSUS						
	0	6. 3	6. 0	6. 2	6. 3	5. 8
	2	7. 0	7. 0	7. 1	6. 7	6. 7
	4	----	6. 2	----	6. 0	6. 8

TABLE 46.—*Analysis of variance on orthogonic data (January and August samples) for lean flavor scores of ribeye from broiled steaks*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	13. 79	3. 44	**8. 60
Years	2	3. 13	1. 51	*3. 78
Month	1	. 59	. 59	1. 48
Aging	1	11. 78	11. 78	**29. 45
Classes × month	4	3. 61	. 90	2. 25
Classes × aging	4	1. 86	. 46	1. 15
Month × aging	1	3. 96	3. 96	**9. 90
Classes × month × aging	4	1. 88	. 47	1. 18
Error	38	15. 21	. 40	---------
Total	59	55. 81	----------	---------

The significant mean differences were:

(*a*) Month × aging:

Aging	*Jan.*	*Aug.*
0	7. 14	6. 63
2	7. 40	7. 62

The mean flavor score for August samples was increased more by aging than that for January samples.

(*b*) Aging:

0	2 weeks
6. 88	7. 51

(*c*) Years:

2d	1st	3d
6. 97	7. 31	7. 32

(*d*) Carcass grade and weight:

C_4	C_1	C_5	C_3	C_2
6. 80	6. 88	7. 18	7. 44	7. 70

TABLE 47.—*Tenderness scores for* Longissimus dorsi *and* Semitendinosus *of broiled steaks from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
June	0	6.4	6.1	4.5	4.4	----
	2	7.7	7.0	6.6	7.0	----
	4	7.2	7.1	6.9	6.9	----
August	0	5.6	6.7	3.8	5.2	4.6
	2	7.5	7.6	6.8	7.5	6.6
	4	8.2	7.6	7.8	7.7	6.6
October	0	----	----	4.5	5.3	4.6
	2	----	----	7.2	6.9	6.9
	4	----	----	7.7	7.1	6.9
January	0	6.0	7.0	4.9	5.3	4.4
	2	7.6	7.5	7.3	6.8	6.4
	4	8.4	7.3	7.3	6.9	6.9
SEMITENDINOSUS						
	0	5.5	4.6	4.6	4.6	3.2
	2	7.2	6.2	6.7	5.9	5.6
	4	----	6.7	----	6.2	6.4

TABLE 48.—*Analysis of variance on orthogonic data (January and August samples) for tenderness scores of ribeye from broiled steaks*

Source	*d. f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	54. 59	13. 62	**11. 64
Years	2	8. 43	4. 21	*3. 60
Month	1	. 80	. 80	---------
Aging	1	86. 02	86. 02	**73. 52
Classes × month	4	3. 64	. 91	---------
Month × aging	1	1. 28	1. 28	1. 09
Classes × aging	4	14. 84	3. 71	*3. 17
Classes × month × aging	4	2. 14	. 53	---------
Error	38	44. 46	1. 17	---------
Total	59	216. 10	----------	---------

The significant mean differences were:

(*a*) Classes × aging interaction:

Aging:	C_1	C_2	C_3	C_4	C_5
0	4. 65	6. 48	6. 88	4. 41	5. 12
2	6. 46	7. 60	7. 59	7. 10	7. 24

The effect of aging was much more pronounced on Good grade, especially light Good, than on Prime grade, especially heavy Prime.

(*b*) Aging:

0	2 weeks
5. 50	7. 20

(*c*) Years:

1st	2d	3d
6. 09	6. 25	6. 72

(*d*) Carcass grade and weight:

C_1	C_4	C_5	C_2	C_3
5. 55	5. 75	6. 18	7. 04	7. 23

Table 49.—*Juiciness scores for* Longissimus dorsi *and* Semitendinosus *of broiled steaks from carcasses of different grades and weights after different aging periods*

[Figures are averages of values from 3–9 carcasses]

Month slaughtered	Aging period (weeks)	Class				
		C_2	C_3	C_4	C_5	C_1
LONGISSIMUS DORSI						
June	0	6. 8	6. 9	6. 1	6. 6	----
	2	7. 4	7. 0	6. 4	7. 1	----
	4	7. 2	7. 5	6. 5	6. 8	----
August	0	7. 1	7. 0	5. 5	6. 0	6. 6
	2	7. 2	7. 1	5. 9	6. 6	6. 8
	4	7. 8	7. 2	6. 7	6. 1	5. 9
October	0	----	----	5. 7	6. 6	6. 5
	2	----	----	6. 4	6. 8	6. 8
	4	----	----	5. 5	6. 1	6. 2
January	0	6. 6	7. 5	6. 4	7. 2	7. 1
	2	7. 0	7. 3	6. 8	6. 4	6. 6
	4	--------	7. 0	5. 8	7. 0	6. 3
SEMITENDINOSUS						
	0	5. 7	5. 6	5. 4	5. 1	5. 0
	2	6. 2	5. 5	5. 8	5. 0	5. 4
	4	----	6. 0	----	5. 5	5. 8

Table 50.—*Analysis of variance on orthogonic data (January and August samples) for juiciness scores of ribeye from broiled steaks*

Source	*d.f.*	*Sum of squares*	*Mean square*	*F*
Classes	4	14. 72	3. 68	*4. 66
Years	2	2. 74	1. 37	1. 73
Month	1	2. 91	2. 91	3. 68
Aging	1	. 04	. 04	---------
Classes × month	4	4. 95	1. 23	1. 56
Classes × aging	4	1. 49	. 37	---------
Month × aging	1	1. 44	1. 44	1. 82
Classes × month × aging	4	2. 67	. 66	---------
Error	38	29. 97	. 79	---------
Total	59	60. 93	----------	---------

The significant mean differences were:

(*a*) Classes:

C_4	C_5	C_1	C_2	C_3
6. 15	6. 78	6. 88	6. 98	7. 20

TABLE 51.—*Characteristics of raw, unaged* Longissimus dorsi *at different positions in carcasses of different grades and weights*

Carcass grade and weight	No.	Marbling rating			Specific conductance 10^{-5} mhos			Shear strength (pounds)			Fat (percent)			Soluble protein (percent)			Collagen (percent by volume)			Autolysis rating		
		11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib
Light Prime	I	2	2	2	352	347	321	6.5	6.5	6.4	------	------	------	------	------	------	1.8	1.0	1.3	1.0	2.0	1.0
	II	3	3	2	388	364	378	3.3	3.3	3.5	5.3	5.7	6.1	5.1	5.0	4.5	.9	1.1	.9	2.0	2.0	1.0
	III	4	4	4	332	310	310	7.4	5.3	4.8	5.5	4.4	6.4	4.4	4.7	4.7	1.3	.7	1.0	1.0	1.0	.5
	IV	3	4	4	269	275	251	6.3	2.8	2.3	5.3	5.3	6.5	5.6	5.7	5.3	.5	.7	.6	1.0	1.0	.5
	Average	3.0	3.3	3.0	335	324	315	5.9	4.5	4.3	5.4	5.1	6.3	5.2	5.1	4.8	1.1	.9	1.0	1.3	1.5	.8
Heavy Prime	I	3	3	3	244	239	275	7.1	5.1	5.7	11.5	9.5	10.2	3.4	3.0	3.4	1.0	1.3	.9	1.0	1.0	1.0
	II	2	2	1	303	261	251	6.8	8.3	6.6	7.6	8.2	9.4	4.6	4.1	4.3	2.1	1.8	1.3	2.0	1.0	1.0
	III	1	2	2	211	234	236	4.8	6.3	4.5	9.2	9.0	9.1	4.8	4.6	4.5	1.1	.3	1.1	1.0	1.0	1.0
	Average	2.0	2.3	2.0	253	245	254	6.2	6.6	5.6	9.4	9.2	9.6	4.3	3.9	4.1	1.4	1.1	1.1	1.3	1.0	1.0
Light Good	I	4	3	3	211	209	287	7.9	7.5	6.4	2.4	3.1	3.4	------	------	------	1.2	.9	.8	0	0	.8
	II	4	4	3	378	383	373	3.5	2.0	3.4	3.2	3.2	3.8	4.8	4.7	5.0	1.1	1.0	1.4	2.0	2.0	2.0
	III	4	4	4	193	159	211	5.9	7.2	5.6	2.3	2.0	3.4	4.5	4.9	5.1	1.0	1.4	1.3	0	0	1.0
	IV	4	3	3	206	234	278	3.4	5.0	5.4	2.8	3.3	3.2	5.3	5.1	5.4	2.0	1.1	1.2	0	.5	.5
	V	3	3	3	218	267	267	6.1	4.7	3.0	3.6	4.1	4.6	5.7	5.5	5.4	.9	.5	.9	1.0	2.0	.5
	Average	3.8	3.4	3.2	241	250	283	5.4	5.3	4.8	2.9	3.1	3.7	5.1	5.0	5.2	1.2	1.0	1.1	.6	.9	1.0
Heavy Good	I	4	4	4	284	269	327	7.4	7.8	8.7	5.1	8.8	8.4	------	------	------	1.3	.6	.9	0	.5	2.0
	II	3	2	2	259	287	261	5.3	5.1	5.4	5.0	5.2	6.8	5.1	4.9	5.1	1.0	1.2	1.0	1.0	1.0	1.0
	III	3	3	3	253	297	327	4.9	4.9	4.2	3.3	3.8	5.9	------	5.5	4.9	1.2	1.4	1.2	1.0	.5	1.0
	IV	4	4	3	269	306	284	8.1	7.3	6.3	2.9	3.7	5.0	5.0	5.2	4.5	1.7	1.1	.8	0	.5	.5
	V	3	3	3	230	259	217	5.5	4.8	4.4	4.5	5.3	6.1	5.6	5.5	5.1	1.1	1.2	.8	1.0	2.0	1.0
	Average	3.4	3.2	3.0	259	284	283	6.2	6.0	5.8	4.2	5.4	6.4	5.2	5.3	4.9	1.3	1.1	.9	.6	.9	1.1
Commercial cow	I	3	3	3	267	303	269	5.2	5.4	6.4	5.8	6.5	6.7	------	------	------	1.0	.9	.5	.5	2.0	.5
	II	2	2	2	259	303	303	5.0	4.3	6.2	5.1	5.6	6.9	5.3	5.3	5.3	1.3	1.5	1.7	1.0	1.0	1.0
	III	4	4	4	287	287	310	7.6	8.9	6.9	3.2	4.5	4.0	4.3	4.0	4.3	2.2	2.7	1.3	.5	0	0
	IV	4	4	4	131	246	220	9.9	3.8	7.7	3.3	3.4	5.6	6.1	6.3	5.7	1.3	1.7	1.5	0	.5	1.0
	Average	3.2	3.2	3.2	236	285	276	6.9	5.5	6.8	4.4	5.0	5.8	5.2	5.2	5.1	1.5	1.7	1.3	.5	.9	.6

TABLE 52.—*Characteristics of cooked, unaged* Longissimus dorsi *from different positions in carcasses of different grades and weights*

Carcass grade and weight	No.	Shear strength (pounds)			Specific conductance 10^{-5} mhos			Soluble protein (percent)			Collagen (percent by volume)			Lean flavor score			Tenderness score			Juiciness score		
		11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib	11–12 rib	9–10 rib	7–8 rib
Light Prime	I	10.7	11.1	10.6	259	246	251	------	------	------	0.8	0.9	0.6	7.7	7.3	7.5	7.3	6.8	7.3	7.0	6.8	6.5
	II	3.5	4.5	5.9	297	273	249	0.45	0.38	0.32	.5	.5	.4	8.2	8.2	7.8	8.5	7.5	7.5	8.3	6.8	7.2
	III	9.4	6.1	5.3	239	228	244	.46	.43	.56	.8	.7	.7	6.8	6.7	6.8	5.3	6.2	7.5	6.7	7.2	7.8
	IV	10.0	8.8	9.9	171	154	123	.42	.69	.41	1.1	.5	.4	7.5	7.5	7.7	7.0	8.2	7.5	7.7	8.2	7.2
	Average	8.2	7.6	7.9	242	223	217	.44	.50	.40	.8	.7	.5	7.6	7.4	7.5	7.0	7.2	7.5	7.4	7.3	7.2
Heavy Prime	I	6.9	6.2	5.8	196	138	163	.55	.40	.60	.4	.5	.6	7.7	7.7	8.2	7.0	8.0	8.3	7.5	7.5	7.8
	II	10.4	12.2	12.3	230	181	186	1.39	2.14	------	1.3	1.0	.8	7.8	8.0	8.5	5.7	6.0	5.8	7.2	8.2	7.5
	III	7.0	6.4	6.5	114	160	129	1.14	.99	1.58	.9	.3	.7	7.7	7.8	8.0	6.8	7.0	7.2	6.8	7.3	7.7
	Average	8.1	8.3	8.2	180	160	159	1.03	1.18	1.09	.9	.8	.7	7.7	7.8	8.2	6.5	7.0	7.1	7.2	7.7	7.7
Light Good	I	14.9	22.7	16.1	261	290	275	------	------	------	.7	.7	.7	6.0	6.0	6.4	4.0	4.0	5.2	5.8	5.8	6.3
	II	4.3	6.2	6.4	303	261	230	.83	.59	.57	.7	.6	.7	6.8	7.0	6.7	6.8	6.8	6.3	6.8	6.8	6.8
	III	14.0	16.7	17.4	223	198	213	.54	.37	1.01	.5	.5	.5	6.2	6.3	5.8	4.5	4.2	5.7	5.8	5.7	6.2
	IV	10.8	10.0	10.6	207	223	171	.66	.74	.59	1.0	.8	.8	6.0	6.7	7.3	3.7	5.3	6.7	5.3	6.3	6.3
	V	13.4	15.3	16.0	183	183	162	.42	.73	.66	1.0	.5	.6	6.7	6.5	7.0	4.7	5.8	5.2	6.0	7.2	6.2
	Average	11.5	14.2	13.3	235	231	210	.61	.61	.71	.8	.6	.7	6.3	6.5	6.6	4.7	5.2	5.8	5.9	6.4	6.4
Heavy Good	I	13.3	13.4	10.6	256	256	246	------	------	------	.7	.7	.8	7.2	7.2	7.0	6.0	6.3	6.8	6.8	6.0	6.3
	II	19.8	12.9	10.1	226	202	205	.94	1.03	.64	1.1	1.0	1.0	6.8	6.4	7.2	5.2	4.8	5.2	8.0	5.8	5.2
	III	11.2	10.6	9.1	253	244	207	.36	.57	------	.9	1.0	.9	6.7	7.3	6.8	5.5	6.5	6.2	5.3	6.7	6.2
	IV	8.6	7.9	6.3	166	223	196	.60	.30	.80	1.1	.5	.6	7.0	6.8	7.7	6.2	7.0	6.0	6.0	6.8	5.8
	V	8.9	8.4	8.0	217	162	189	.80	.83	.65	.7	.6	.6	6.8	7.3	7.5	5.8	6.7	5.7	6.7	6.2	6.2
	Average	12.4	10.6	8.8	224	217	208	.63	.63	.70	.9	.8	.8	6.9	7.0	7.2	5.7	6.3	6.0	6.6	6.3	5.9
Commercial Cow	I	13.2	13.7	15.4	273	241	217	------	------	------	.6	.6	.6	7.0	6.8	6.3	3.8	5.0	4.8	6.8	6.2	5.5
	II	14.9	14.2	10.0	244	234	198	.44	1.06	.81	1.1	1.0	.9	6.7	7.2	7.0	4.0	4.2	5.7	6.2	5.5	6.5
	III	10.3	10.6	11.4	160	181	140	.36	.44	.36	2.2	2.7	1.3	7.0	6.8	7.5	6.2	6.7	5.3	6.3	7.3	5.5
	IV	15.3	13.3	13.3	204	181	187	.53	------	.78	.9	1.2	.9	6.2	5.8	6.8	3.2	3.6	4.4	6.2	5.0	5.8
	Average	13.4	13.0	12.5	220	209	186	.44	.75	.65	1.2	1.4	.9	6.7	6.7	6.9	4.3	4.9	5.1	6.4	6.0	5.8

TABLE 53.—*Comparison of* Longissimus dorsi, *raw and cooked, from right and left sides of Prime and Good grade carcasses*

RAW

	Light Prime				Heavy Prime				Light Good				Heavy Good			
Aging period (weeks)	0		2		0		2		0		2		0		2	
Side Rib position	Right 12th	Left 12th	Right 10th	Left 10th	Right 12th	Left 12th	Right 10th	Left 10th	Right 12th	Left 12th	Right 10th	Left 10th	Right 12th	Left 12th	Right 10th	Left 10th
Marbling rating	4.0	4.0	1.0	2.0	2.0	2.0	1.0	2.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0	2.0
Shear strength (pounds)	5.9	4.9	6.6	6.0	5.2	3.0	4.2	1.8	4.8	4.5	2.9	3.8	6.4	4.9	5.7	6.1
Specific conductance—10^{-5} mhos	269	225	211	209	215	196	215	164	321	303	300	284	323	317	244	269
Fat (percent)	6.0	4.1	----	----	10.2	9.6	----	----	4.0	4.0	2.4	----	5.7	4.3	6.5	5.0
Soluble protein (percent)	5.5	6.2	4.8	4.3	4.9	4.5	4.2	3.3	5.2	5.2	4.8	4.5	4.6	5.0	2.6	4.4
Collagen (percent by volume)	.6	.5	1.1	.7	.8	.8	1.8	1.0	.8	.8	.7	.8	1.2	1.1	1.2	1.3
Autolysis rating	.8	1.0	2.0	3.0	0	0	2.0	.5	.5	4.0	2.0	2.0	2.0	1.0	2.0	1.0

COOKED

Rib position	Right 11th	Left 11th	Right 9th	Left 9th	Right 11th	Left 11th	Right 9th	Left 9th	Right 11th	Left 11th	Right 9th	Left 9th	Right 11th	Left 11th	Right 9th	Left 9th
Shear strength (pounds)	9.1	10.0	6.5	9.2	6.0	6.4	5.0	6.4	9.9	8.4	6.7	6.5	11.5	11.7	11.1	8.5
Specific conductance—10^{-5} mhos	162	150	143	95	158	158	144	133	239	241	186	170	213	205	213	230
Soluble protein (percent)	.74	.80	.85	.46	1.19	1.07	.71	.79	.26	.37	.98	1.03	.38	.49	.83	.79
Collagen (percent by volume)	.4	.4	.7	.4	.6	.7	1.3	.8	.5	.4	.6	.7	1.0	1.0	.8	.5
Lean flavor score	7.7	6.5	7.7	8.0	7.5	7.0	8.3	7.2	6.2	6.8	6.8	6.7	6.5	6.3	6.7	6.2
Tenderness score	6.0	4.8	6.8	7.5	8.5	7.2	9.3	7.8	4.8	5.0	7.7	7.0	5.3	4.0	5.0	5.0
Juiciness score	6.7	7.3	6.3	6.7	8.5	8.2	8.5	6.7	6.0	6.0	6.2	6.2	5.5	5.2	6.0	5.2

TABLE 54.—*Linear correlation coefficients between tenderness and other properties of ribeye*

	Year	Aging period (weeks)					
		0		2		4	
		n	r	n	r	n	r
Carcass fat	1	42	**0. 6574	----	----------	----	----------
	2	42	**. 5585	----	----------	----	----------
	3	31	. 1097	----	----------	----	----------
Intramuscular fat	1	42	**. 6149	42	0. 0856	38	0. 1295
	2	42	**. 5976	39	*. 2966	20	. 1450
	3	34	*. 3964	34	**. 3964	----	----------
"Linear" fat	1	42	*. 3327	----	----------	----	----------
	2	42	**. 5018	39	. 0474	20	. 0448
	3	34	—. 1580	34	. 1222	----	----------
Marbling rating	2	42	**—. 5620	39	*—. 3327	20	**—. 5983
	3	34	—. 2023	34	*—. 3678	----	----------
Shear strength, cooked	1	42	**—. 6723	42	**—. 3854	38	. 2484
	2	42	**—. 8273	39	**—. 3951	20	—. 3641
	3	34	**—. 7982	34	**—. 5297	----	----------
Specific conductance, raw	1	42	**. 5054	42	—. 0415	41	—. 0316
	2	42	**. 4876	38	—. 0698	19	. 1754
	3	34	. 0010	34	—. 1467	----	----------
Autolysis rating	1	42	. 1336	42	. 0130	40	—. 0220
	2	42	**. 7422	39	. 0305	20	—. 0650
	3	34	. 1219	34	. 0968	----	----------
Lean color rating	1	36	—. 2362	36	—. 2626	41	—. 1385
	2	42	*—. 3134	39	—. 2113	20	—. 1247
	3	34	**—. 5641	34	—. 2228	----	----------
Collagen, raw	1	42	—. 1224	42	*—. 3704	40	**—. 4718
	2	42	—. 1025	39	—. 2257	20	. 0860
	3	34	—. 1163	34	—. 1110	----	----------
Collagen, cooked	1	29	—. 1316	32	—. 1947	27	—. 3343
	2	42	—. 2392	39	—. 1855	20	. 0694
	3	34	—. 1641	34	—. 1452	----	----------
Penetrometer, raw	2	39	—. 0430	38	—. 0192	20	—. 1816
	3	33	—. 0276	34	—. 2631	----	----------

TABLE 55.—*Linear correlation coefficients between juiciness and other properties of ribeye*

	Year	Aging period (weeks)					
		0		2		4	
		n	r	n	r	n	r
Carcass fat	1	42	**0. 4495				
	2	42	**. 4731				
	3	31	. 0924				
Intramuscular fat	1	42	**. 3927	42	0. 2071	38	**0. 4850
	2	42	**. 6510	39	**. 6013	20	**. 5514
	3	34	*. 3806	34	**. 5170	----	----------
Marbling rating	2	42	**—. 5931	39	**—. 8199	20	**—. 7849
	3	34	**—. 4923	34	**—. 5376	----	----------
Fiber autolysis rating	1	42	. 1986	42	—. 0013	40	—. 1200
	2	42	**. 4991	39	—. 1832	20	. 1880
	3	34	—. 1957	34	. 0959	----	----------
Lean color rating	1	36	—. 0156	36	—. 1553	41	—. 2315
	2	42	. 0497	39	—. 1410	20	. 0280
	3	34	—. 0719	34	—. 2268	----	----------

TABLE 56.—*Linear correlation coefficients between lean flavor and some chemical constituents of raw and cooked ribeye*

	Year	Aging period (weeks)					
		0		2		4	
		n	r	n	r	n	r
Creatine, raw	1	42	—0. 0814	42	—0. 0499	41	—0. 0121
	2	42	. 1644	39	*—. 3596	20	—. 2946
Creatine, cooked	1	42	. 1398	42	—. 1188	38	—. 1144
	2	42	—. 0849	38	—. 0374	20	—. 0912
Creatinine, raw	1	42	—. 2084	39	*. 3469	41	—. 0138
	2	42	*. 3138	39	. 1133	20	. 0870
Creatinine, cooked	1	41	. 2831	39	. 1454	38	—. 1239
	2	41	. 1277	38	**. 9125	20	. 2071
Creatine/creatinine, cooked	1	50	—. 1552	51	—. 2048	44	—. 0645
Soluble protein, cooked	3	49	. 1747	30	. 0143	18	. 0908

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